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R W CASS ET AL. AUG 82 USCG-D-04-82 DTCG23-80-C-20001

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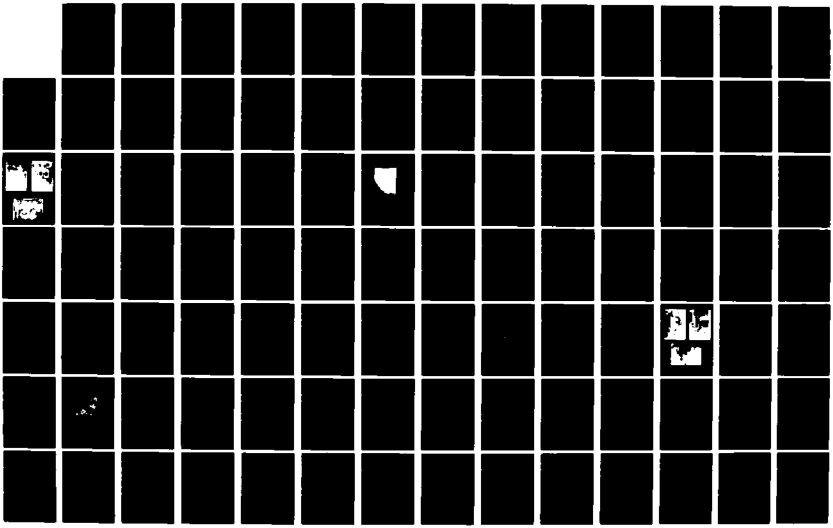

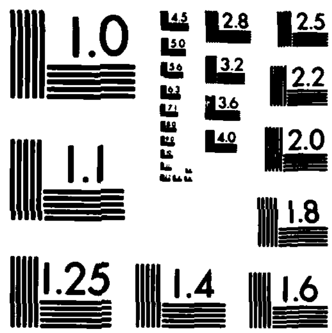

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NATIONAL BUREAU OF STANDARDS-1963-A

Report No. CG-D-04-82

Shoreside Boiler Demonstration of Fuel-Water Emulsions

R.W. Cass
T.J. Pakula
P.J. Vollemans

Seaworthy Engine Systems, Inc.

ESSEX, CT. 06426

AUGUST 1982
FINAL REPORT

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
United States Coast Guard
Office of Research and Development
Washington, D.C. 20593

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16. Abstract

Efficiency and emission (particulate and NO_x) measurements were performed on a U.S. Coast Guard shoreside boiler. The purpose of the program was to assess any benefits and/or penalties associated with firing a water-in-oil emulsion. The project included installation of instrumentation required for efficiency measurements, identification and installation of a suitable low energy emulsifier and metallographic analysis of tube samples to determine corrosion and erosion due to firing an emulsified fuel for a heating season. Closely controlled tests were performed over the operating load range on the cleaned and tuned boiler firing both neat (straight) oil and emulsified oil. These tests were repeated after firing each of the respective oils for one normal heating season. The results showed the biggest gains in efficiency from boiler cleaning and tuning. There were no significant differences in efficiency when firing neat and emulsified oil. The boiler was slightly cleaner after firing emulsified fuel for the heating season. The particulate emissions were less for emulsified oil firing and excess air could be trimmed closer to stoichiometric. There were no significant differences in NO_x emissions. Firing an emulsified fuel was more economic than firing neat oil, however, the difference was minimal. There was no evidence of tube erosion or corrosion.

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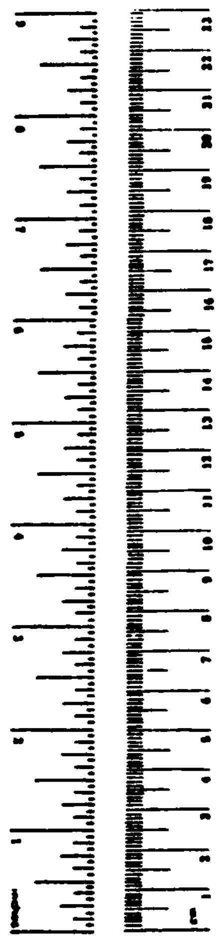
PREFACE

This work was performed for and under contract to the Department of Transportation, United States Coast Guard, Office of Research and Development. The Coast Guard technical representative for the project was Mr. Fred Weidner. Testing was performed at the U.S.C.G. Academy and the following members of the Coast Guard were instrumental in the conduct of the program: CWO Land, CWO Cushing, MKCS Isherwood, MK1 Brooks, MK1 Davenport, MK1 Tardiff and the boiler room watchstanders and maintenance personnel. The project's major subcontractors and their areas of expertise are as follows: Ajax Engineering Co., Inc. - Boiler fireside and waterside cleaning; Eastern Analytical Laboratory - Water analysis; Fuel Engineering Company of New York - Fuel analysis; Irving W. Glater, P.E., C.S.P. - Boiler tube material and deposit analysis; The Bigelow Company - Boiler tube sample installation and removal; and TRC Environmental Consultants, Inc. - Flue gas emission testing.

METRIC CONVERSION FACTORS

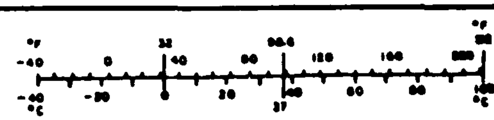
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1.0 EXECUTIVE SUMMARY AND INTRODUCTION

1.1 Executive Summary

Efficiency and emission (particulate and nitrogen oxide) measurments were performed on a shoreside boiler. The purpose of the program was to assess any benefits and/or penalties associated with firing a water in oil emulsion. The project included installation of instrumentation required for efficiency measurements, identification and installation of a suitable low energy emulsifier and metallographic analysis of tube samples to determine corrosion and erosion due to firing an emulsified fuel for a heating season. Closely controlled tests were performed over the operating load range on the cleaned and tuned boiler firing both neat (straight) oil and emulsified oil. These tests were repeated after firing each of the respective oils for one normal heating season. This brief summary of the findings of the test program are directly applicable to boiler number 3 at the U.S.C.G. Academy and may be relevant to similar boiler installations using comparable fuels. However, they should not be considered applicable to all boilers.

The following conclusions are drawn from the test measurement data:

* there was no significant improvement in boiler efficiency associated with firing a 6% water in oil emulsion (emulsified oil) in a cleaned and tuned boiler.
* the boiler's firesides were slightly cleaner after firing emulsified fuel for one (1) heating season as compared to a similar period of firing neat oil
* the boiler's slightly lower operating expenses, when firing an emulsified fuel, do not justify the purchase of the emulsion fuel system
* flue gas particulate emission rates were reduced an average 43% (high load tests) and 27% (low load tests) when firing an emulsion at excess air levels similar to those during neat oil tests

* no reduction in nitrogen oxide emission rate was believed to result from the burning of an emulsified fuel

* the required soot blowing frequency could be increased from every five (5) days on neat oil to every seven (7) days on emulsified fuel

* there was no measurable erosion or corrosion of boiler tube surfaces due to firing emulsified fuel for one typical heating season

* boiler cleaning and tuning returned the unit to near design operating efficiency and amounted to 0.6% to 2.9% recovery in efficiency, dependent upon operating load

* the boiler's chemical treatment was sufficient to maintain waterside cleanliness for many years with only annual high pressure water washing

1.2 Background

The operating expense of a particular boiler burning fuel oil at a certain load is basically dependent upon the unit's combustion and thermal efficiencies. If it were possible to operate a boiler with combustion at zero percent excess air (stoichiometric condition), the operating expense would be minimum and no degradation in thermal efficiency would occur because the dry powdery ash residue would be blown out of the boiler with the flue gas. Unfortunately, only textbook boilers can be operated at theoretical conditions.

Most industrial boilers operate with too much excess air, produce soot and smoke, discharge particulates, experience increasing tube deposits and decreasing heat transfer efficiency with time, and require periodic downtime for manual cleaning. There are new concepts being employed which attempt to improve fuel oil atomization and thereby reduce the impact of the above noted factors. One approach is the use of water in fuel emulsions, whereby water droplets entrained in the fuel flash to steam and enhance the fuel's atomization to promote improved combustion efficiency.

Water in fuel emulsions in boiler applications is today, and

has been for several years, the subject of considerable attention as a method of energy (fuel) conservation. A list of pertinent references is included in Appendix A. The combustion process of water in fuel emulsions is based on the exploitation of the "micro explosion" phenomenon which reduces the heterogeneity and localized high temperatures associated with non-uniform, diffusion limited combustion. These micro-explosions of the water particles within the fuel droplets cause a secondary atomization effect that greatly improves the overall atomization quality without modifying the actual boiler combustion equipment. The resulting improved atomization decreases the time to completely burn each fuel droplet in the firebox and thereby reduces the unburned fuel (carbon and coke) that leaves the furnace. The major potential benefits from this improved combustion efficiency have been, as a result of both laboratory testing and industry applications, identified to be as follows:

* Improved boiler thermal efficiency, as a result of reduced boiler excess air levels.
* Reduced nitrogen oxide (NO_x) emissions because less oxygen is available to react with the nitrogen in the air to form oxides of nitrogen.
* Reduced particulate emissions are the results of more complete combustion of the fuel.
* Reduced boiler tube fouling rates and soot blowing frequency because of more complete combustion of the fuel.

While the above identified benefits have been associated with the utilization of water in fuel emulsions in boiler operation, their measured value, both singularly and in combination, can and has varied significantly as a function of a variety of boiler and operational variables. That is to say, a standard percentage reduction in fuel consumption or a common dollar savings in maintenance expenditures cannot be expected for all emulsion applications. The following are some of the major influencing variables which will impact the potential level of efficiency, maintenance and

operating cost improvement when using water in fuel emulsions.

* Fuel Quality: The poorer the quality of fuel the greater the potential for improvement in combustion efficiency. Low sulfur fuels, less than .5% for example, having some distillate content exhibit better combustion characteristics than their high sulfur counterparts. Consequently, the benefits, efficiency improvement and emissions level reduction would be less when using low sulfur as compared to high sulfur fuel types.

* Boiler Operating Condition: A number of factors are included in this category, all of which will, in varying degrees, impact the degree of performance, emission level, and maintenance improvement.

* Physical Condition: The actual physical condition of the boiler itself and it's supporting equipment is directly related to the boiler's level of operating performance and therefore, to the amount of lost performance recoverable through the use of a combustion aid (emulsifier), to approach the design performance level. Some specific items relative to physical condition include: leaking boiler casings, deteriorated or missing gas path baffles, extensive loss of heat transfer surface (plugged tubes), deteriorated burner registers and/or diffusers, worn burners and/or burner tips and cleanliness of heat transfer surfaces.

* Level of Tuning: The condition and set points of the combustion control system significantly and directly effect the operating performance of the boiler. The combustion control system maintains the excess air level at load and during load changes. The burner tip, diffuser and register orientation can also effect combustion efficiency through direct impingement or insufficient mixing of fuel and combustion air.

* Boiler Support Systems' Condition: Marginal or deteriorated boiler support systems have the potential of adversely impacting boiler performance. Specific examples would include insufficient fuel oil preheat to obtain the required viscosity

for good atomizaton and insufficient fan capacity to supply adequate combustion air.

* Boiler Practices: Frequently excessive fuel consumption and increased maintenance costs can be attributed to operator practices. Lack of attention to excess air levels; operation with improper fuel viscosities; careless soot blowing procedures are examples of the human element contributing to inefficient operation.

Unfortunately, all of these conditions exist either alone or in combination in a large number of steam generating plants. Depending upon the actual situation, off-design performance can be as little as one or two percent or in excess of ten percent. The cost of corrective action might be nominal as in the case of burner tip replacement or could be exceedingly high if, for example, a total burner system replacement is made. In recent years, the emulsifier has been promoted as a cure for the aforementioned conditions. The approaches taken, relative to the application of water in fuel emulsions, have varied widely. Decisions to install emulsifiers have been made on purely technical bases, for economic reasons and in some cases as a result of an exceptional sales approach. The requirements to meet EPA emissions standards or the need to burn degraded fuels are examples of the technical basis. Partial efficiency recovery by the application of an emulsifier as an alternate to high capital inventment for boiler repairs and equipment replacement would be considered as an economic decision. Finally, the installation of an emulsifier as a cure-all or as an opportunity to exceed boiler design performance levels might be considered as the result of both not understanding the technical problems and an outstanding sales effort.

Whatever the particular reasons for the application of water in fuel emulsion, a large number of emulsifying devices have been installed in steam boiler plants. A number of formal and informal test programs have been conducted by boiler operators and emulsifier manufacturers. The results of these evaluation programs have

been dependent upon two major factors. They are:

* The Evaluating Organization - the user, or the emulsifier manufacturer. In either case there exists a potential for subjective influences in the evaluation.

* The Technical Approach - because of a large number of controllable and uncontrollable factors influencing the tests, the results of user or manufacturer evaluation programs are often restricted to a few specific technical or economic areas. These influencing factors include, for example, unique operating requirements, absence of adequate and sufficient instrumentation, limited resources (financial and personnel) and others. Further, results are often proprietary and therefore not available to the general public.

In summary, while specific benefits of water in fuel emulsions have been identified in both laboratory and field installations, there has not been, prior to this program, an independently conducted, detailed and controlled field test program to both confirm and quantify these benefits. Neither has such a program addressed any potential adverse consequences of water in fuel emulsion firing in a shoreside boiler installation.

The United States Coast Guard has, for a number of years, been involved in the investigation of water in fuel emulsions. Prior to this program an in-depth evaulation of water in fuel emulsions for diesel engine applications was conducted by Southwest Research Institute under contract to the U.S.C.G. Office of Research and Development. A primary objective in that program was to assess the fuel economy benefit of emulsion systems being applied to the U.S.C.G. diesel fleet. Similarly, since the U.S.C.G. operates a large number of shoreside boilers, the potential benefits of emulsion firing in these installatins was obviously of interest. Accordingly, a program was initiated by the Office of Research and Development to demonstrate and assess the benefits of water in fuel emulsions in a shoreside boiler.

1.3 Objectives

The major objective of the thorough test program described herein was the identification and quantification of the benefits directly attributable to the use of water in fuel emulsions in a shoreside boiler. The potential benefits were identified at the beginning of the test program to be:

* Improved combustion and thermal efficiency (fuel economy)
* Reduced flue gas emissions (particulates and NO_x)
* Reduced fireside fouling rate (slower performance degradation)
* Reduced maintenance requirements (longer intervals between fireside cleaning)

In addition to the definition of the aforementioned benefits, a program objective was the identification of any negative consequences of operating with water in fuel emulsions. These, for example, were tentatively identified to be increased tube erosion or corrosion, due to higher moisture levels in the flue gas and adverse operation situations resulting from the introduction of additional equipment and controls in the fuel oil service system.

It is important to note that a comparison of the emulsifying device used in this program to any other emulsifier was not an objective of this program. Neither should the results of this program be considered as either an endorsement or disapproval of the particular device used. While this emulsifier is considered to be representative of commercially available devices and the boiler test facility is typical of plants of this type, some caution is suggested in the interpretation of test results. When considering the number of variable conditions which exist from power plant to power plant, as previously discussed, the potential benefit to be derived from emulsion firing and the specific type of emulsifying device to be employed must be evaluated on a case basis.

Finally, it should be stated that the emulsifying device employed in this test program was of the commonly referred to low

energy type. These low energy units are so characterized because of their operating principles which typically employ relatively low pressure differentials (100-200 psi) in the generation of the emulsion, and therefore, consume moderate amounts of power. In comparison, the high energy type units have correspondingly higher power demands as a function of the high pressure differentials (typically in excess of 2000 psi). There is a significant level of interest in the low energy, low cost emulsifiers for shoreside boiler plant application and therefore, this type was considered for evaluation.

1.4 Approach

A very detailed and methodical approach was taken to identify and accurately quantify the benefits attributable to water in fuel emulsion firing. Care was taken throughout the program to isolate any benefits of emulsion firing from those normally available from the correct operation of a properly repaired, cleaned and tuned boiler. The following describes the test sequence and methodology, with appropriate supporting rationale utilized in the conduct of this program.

1.4.1 Test Sequence

The program test sequence, together with the objectives for each series of testing, is provided below.

* Preliminary Boiler Tests: Determination of the test boiler's efficiency and emissions levels when operating on neat (non-emulsified, as delivered) fuel prior to any boiler repairs, cleaning, tuning or modification of operating procedures.

* Long Term Neat Oil Tests: This series of testing provided:
  - Identification of percentage of efficiency recovered through boiler cleaning, repair, tuning and proper operation.
  - Establishment of baseline efficiency and emissions levels against which subsequent neat oil and emulsified oil test results would be compared.

- Determination of efficiency degradation rate (fouling rate) when operating with neat oil fuel.

* Boiler Efficiency and Emissions Tests With Emulsified Oil: After optimization of emulsified oil water/fuel ratio, testing was performed to ascertain the level of efficiency and emissions improvements attributable to emulsion firing.

* Long Term Emulsified Oil Test: This series of testing provided, through the comparison of data from pre long term tests with data from post long term tests, an efficiency degradation rate for operating with emulsified oil. This data was then compared to that collected as part of the neat oil long term tests to quantify any benefit attributable to emulsion firing.

At appropriate times during the program the test boiler was cleaned and tuned and the baseline (neat oil) efficiency and emissions tests were performed to verify that there had been no major undetected change in boiler performance and also to provide a good statistical base against which to compare emulsified oil performance data.

1.4.2 Special Test Considerations

To assure to the maximum degree possible and practicable, the validity and accuracy of test data collected, special precautions were taken in the approach to and conduct of testing. Some of the major considerations and precautions are highlighted below.

* Essential to the acquisition of directly comparable test data (neat oil versus emulsified oil) was the elimination or maximum control of all variables in the test program. Typical of the steps taken to achieve this were:

  - the use of one test boiler in the program to avoid differences in boiler performance due to age, condition, or unique idiosyncrasies of individual boilers.

  - the periodic analysis of fuel and water to identify and

quantify any variables of significance which would impact the performance data.

- the careful instruction and supervision of operating personnel to assure consistent practices throughout the test program. Included were specific guidelines relative to items such as excess air levels, fuel oil viscosity control, soot blowing procedures, burner tip-diffuser-barrel position and boiler steam drum level.
- the requirement for periodic boiler cleaning and tuning to assure identical start points to provide valid baseline and emulsion firing data.
- the adherence to identical test procedures for efficiency and emissions measurements at each scheduled test in order to assure valid data comparison.

* In order to obtain both accurate and repeatable data, the test boiler was extensively fitted with test instrumentation (flow measuring devices, pressure, temperature, viscosity and steam quality indicators) meeting the criteria of ASME Power Test Codes. Further, calibration of test instrumentation was performed at appropriate times in the program.

* To assure a high level of confidence in data collection, an automatic data logging system was installed with back-up provided by manual logging of the parameters.

  All efficiency tests were performed in accordance with the requirements of the ASME Power Test Code 4.1. Particulate emissions testing was conducted in accordance with EPA Reference Methods, 1 through 5. Measurement of oxides of nitrogen (NO_x) was performed by continuous monitoring procedures in accordance with standard industry practices.

* To identify any adverse effects of water in fuel emulsion firing relative to tube erosion or corrosion, boiler tube test patches were installed before both the neat oil and

emulsified oil long term test periods.

In summary, as can be seen by the foregoing discussion of the approach taken to achieve the program objectives, maximum precautions were taken to provide accurate and credible results from this field test program.

1.5 Schedule of Major Program Events

In consideration of the rather long period of performance of this contract (in excess of two years) and the extensive number of tests performed, a concise presentation of major program events is considered to be beneficial to achieving a clear understanding of the entire test program and the interrelationship of specific tests and program tasks. Table 1-1 identifies the sequence of major events by calendar month from contract date, April 18, 1980. Figure 1-1 illustrates the program test schedule which was followed.

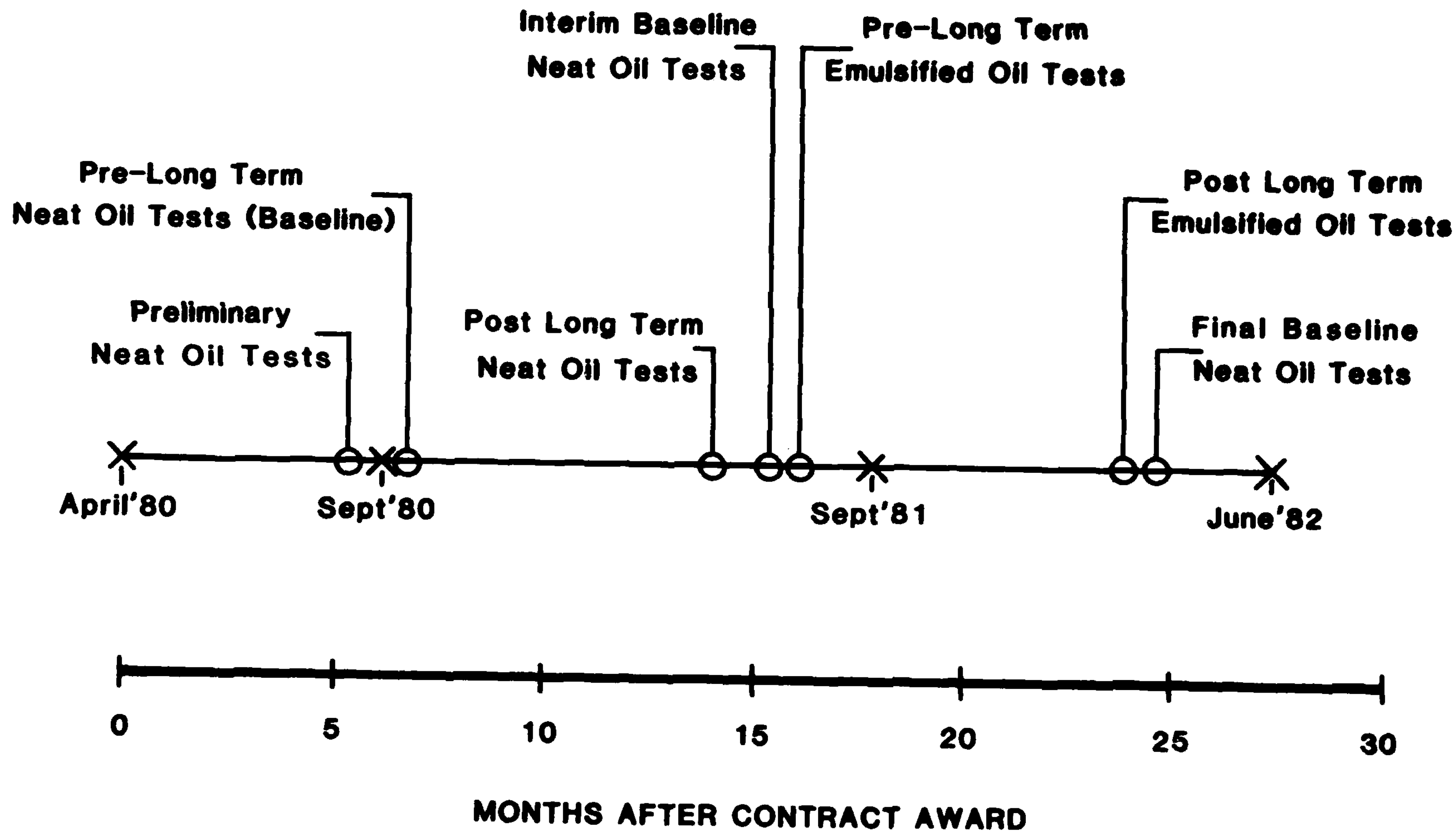
TABLE 1-1

SUMMARY OF MAJOR PROGRAM EVENTS

EVENT	CALENDAR DATE
Contract Award	April 18, 1980
Completed Test Instrumentation Installation	August 6, 1980
Preliminary Neat Oil Tests	August 12-15, 1980
Boiler Cleaning & Repair	August 18-20, 1980
Boiler Inspection	August 21, 1980
Boiler Tube Material Samples Installed	August 25, 1980
Boiler Tuning	September 2-3, 1980
Pre-Long Term Neat Oil Tests	September 4-18, 1980
Emulsifier Selection & Installation Completed	February 18, 1981
Post-Long Term Neat Oil Tests	May 4-13, 1981
Boiler Inspection	May 15, 1981
Replacement of Boiler Tube Material Samples	May 26-27, 1981
Boiler Cleaning & Repair	May 28-June 3, 1981
Boiler Inspection	June 3, 1981
Boiler Tuning	June 4-5, 1981
Interim Baseline Neat Oil Tests	June 8-12, 1981
Emulsified Oil Optimization Tests	June 17-18, 1981
Pre-Long Term Emulsified Oil Tests	June 22-29, 1981
Post-Long Term Emulsified Oil Tests	March 22-30, 1982
Boiler Inspection	April 1, 1982
Removal of Boiler Tube Material Samples	April 5 & 8, 1982
Boiler Cleaning & Repair	April 8 & 9, 1982
Boiler Inspection	April 9, 1982
Boiler Tuning	April 12, 1982
Final Baseline Neat Oil Tests	April 12-15, 1982

Figure 1.1

Program Test Schedule



2.0 PROGRAM DESCRIPTION

The demonstration of water in fuel emulsions was performed at the boiler facility of the United States Coast Guard Academy, New London, Connecticut. Three, approximately equally rated boilers, are installed at this facility and each is independently capable of meeting the entire demand of the U.S.C.G. Academy. Steam demand is comprised of heating, galley, laboratory, hot water, laundry, etc. requirements and is continuous throughout the year with maximum loads occuring during the winter months for facilities heating purposes.

All test boiler operation was carried out by the normal U.S.C.G. watch personnel under the direction of the Contractor. During periods when the test boiler was secured for inspection, cleaning or repairs, one of the back-up boilers was put in service to meet Academy steam demands.

2.1 Test Boiler Selection

An inspection of the three boilers at the facility was performed to select the boiler which would best meet the requirements of the test program. While any one of the three boilers would have been suitable for testing, only boiler number 3's exhaust duct configuration met the minimum requirements of the particulate emissions testing. Specifically, only this boiler had the sufficient length of straight flue duct. While this was the determining factor in the selection process, boiler number 3 coincidently provided several additional advantages over the other boilers.

* The boiler was equipped with the more modern linkage for the forced draft fan damper control and therefore provided a better capability for close control of excess air.
* The physical location of this boiler within the boiler house facilitated installation of the additional equipment, instrumentation, piping, wiring, etc. necessary for the test program.

There was, however, one slightly adverse factor associated

with the use of boiler number 3. Since this unit is the newest of the three boilers at the Academy by approximately ten (10) years, it probably offered the least amount of lost efficiency to be potentially recovered by cleaning, repairs, tuning and emulsion firing as compared to the older two boilers. Consequently, the magnitude of the percent changes required to be measured would be small, even to the point of approaching instrument accuracy. This situation further stressed the need for precise data measurement and analysis.

2.1.1 Boiler Particulars

The particulars of the test boiler are as follows:

Manufacturer:	The Bigelow Company New Haven, CT
Model/Type:	KS20 Two Drum Integral Furnace Water Tube
Year Built:	1966
Rated Capacity:	28,500 LBS/HR
Operating Pressure:	100 PSIG
Design Pressure:	160 PSIG
Heating Surface:	4364 Sq. Ft.
Furnace Volume: (To Top of Hearth)	1060 Cu. Ft.

Figure 2-1 shows a partial view of the test boiler.

2.1.2 Burner System

The boiler is fitted with a Peabody Engineering Corporation burner system comprised of two (2) forced draft air registers with steam atomizing oil burners. Design particulars are:

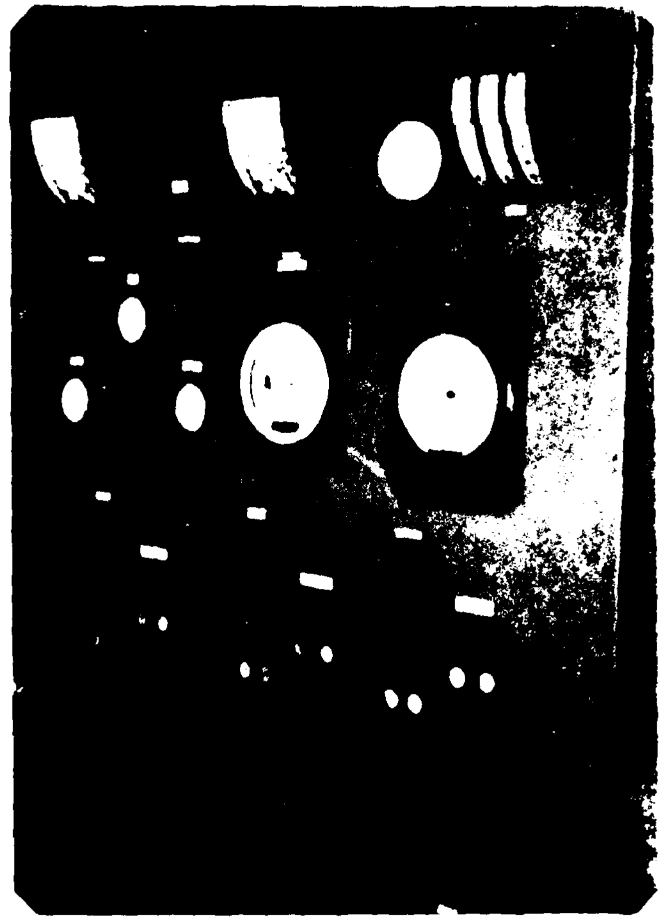
Fuel:	No. 6 Oil
Viscosity:	300 SSU, maximum
Capacity:	1020 LBS F.O./HR/BRNR
Oil Pressure:	70 PSIG
Steam Atomizing Pressure:	90 PSIG

Figure 2-2 provides a close up view of the burner front.

FIGURE 2-1

Test Boiler

FIGURE 2-3



Hagan Combustion Control

FIGURE 2-2

Burner Front

2.1.3 Combustion Control

Automatic combustion control is provided by a typical Hagan Control System. This system maintains constant steam pressure by regulating the rate of air and oil flow to the boiler furnace. Changes in steam demand result in steam pressure changes. These pressure changes cause the system master controller to regulate the forced draft dampers. As the combustion air flow varies as a function of this damper control so does the pressure drop across the burner register. A variable ratio regulator controls the fuel oil regulating valve on the basis of the pressure drop across the registers, thus providing the desired air-fuel ratio.

Figure 2-3 illustrates the Hagan Combustion Control Panel in the boiler facility.

2.2 Test Boiler Instrumentation

Boiler number 3 was originally fitted with sufficient instrumentation to provide for safe operation. This instrumentation included, for example, fuel oil flow meter, temperature and pressure indicators for key parameters such as steam, feed water and fuel oil, and drum level indicators. Additionally, just prior to the start of the test program a continuous monitoring oxygen (O_2) analyzer was installed on the test boiler to provide improved capability for optimum excess air trimming and to facilitate consistent boiler operation by providing a common parameter to which all watchstanders keyed. The test boiler was also equipped with an opacity meter.

The test program objectives and the requirements of the ASME Power Test Code 4.1 necessitated the installation of additional instrumentation and the replacement of others not meeting accuracy criteria. Table 2-1 lists all of the instruments installed on the test boiler and, where applicable, the ASME accuracy requirements. Additionally, a notation is made as to whether the reading is local, recorded on the data logger, or both.

The data logger provided a second set of recorded data in addition to that logged by the watchstanders. The data logger was

TABLE 2-1

TEST BOILER INSTRUMENTATION

Instrument Description	Operating Range	No. of Units	ASME Required Accuracy	Local Reading	Data Logger Reading
Fuel Oil Meter	0-5 gpm	1	± 0.50%	x	x
Feed Water Meter	0-75 gpm	1	± 0.35%	x	x
Steam Flow Meter	0-30,000 lb/hr	1	NA	x	x
Steam Quality Calorimeter	0-5%	1	± 0.20%	x	x
Thermocouple-Steam	0-400°F	1	± 0.25%		x
Thermometer-Steam	0-400°F	1	± 0.25%	x	
Thermocouple-Feed Water	0-300°F	1	± 0.25%		x
Thermometer-Feed Water	0-300°F	1	± 0.25%	x	
Thermocouple-Flue Gas	0-700°F	1	± 0.25%		x
Thermocouple-Fuel Oil	0-300°F	1	NA		x
Thermometer-Fuel Oil	0-300°F	1	NA	x	
Thermocouple-Ambient	0-150°F	1	± 0.25%		x
Pressure Gage-Steam	0-160 psia	1	± 1.00%	x	
Pressure Gage-Feed Water	0-200 psia	1	± 1.00%	x	
Pressure Transducer-Steam	0-160 psia	1	± 1.00%		x
Pressure Transducer-Feed Water	0-200 psia	1	± 1.00%		x
Pressure Transducer-Draft	0-1.0 "H_2O	1	NA		x
Pressure Gage-Fuel Oil	0-160 psig	1	NA	x	
Pressure Gage-Steam Atomization	0-160 psig	1	NA	x	
Viscosity Meter	0-300 SSU	1	NA	x	x
Data Logger	16 channel	1	NA	NA	NA

Note: NA - not applicable

programmed to print on demand, at predetermined intervals (every 15 minutes during the efficiency tests and every 4 hours during the long term tests) and when the programmed steam flow rate of change limits were exceeded. The data logger was programmed to average the readings over the desired intervals. The automatic logger proved to be very beneficial throughout the program by providing highly accurate and repeatable readings and also serving as means to cross-check instruments (transducers versus local gauges).

All instrument calibration was checked between the two long term test periods and at the end of the second (emulsified oil) long term test.

2.3 Emulsifier Selection

An obviously important element in the performance of the program was the selection of the emulsifier to be used in the demonstration and evaluation. A very thorough evaluation procedure was developed to select an emulsifier representative of commercially available state-of-the-art low energy units. The following sections describe the selection process and the evaluation criteria used.

2.3.1 Industry Survey and Solicitation

The initial step in the selection process was the identification of manufacturers and/or distributors of commercially available water/oil emulsifiers. Secondly, manufacturers of equipment capable of making water/oil emulsions but not actually marketing their equipment for this type of application were identified. These included manufacturers of pipeline mixers, colloid mills and static mixers.

A total of thirty-three (33) potential participants were identified and contacted relative to their possible participation in the program. Letters describing the program and questionnaries requesting technical information relative to their emulsifying devices were sent to the thirty-three manufacturers/distributors. Each potential supplier was provided several opportunities to respond to this initial inquiry. It should be noted that this was a worldwide survey, as a number of European manufacturers have had

considerable experience in the field of low energy emulsification. Furthermore, several of these manufacturers have manufacturing and/or distribution arrangements with American companies.

This initial survey and solicitation resulted in the identification of nine (9) manufacturers who had proven, commercially available units, capable of producing a water in oil emulsion, had responded affirmatively to being considered for participation in the program, and, were willing to provide the detailed technical information necessary for the final evaluation procedure.

Additional data was then requested from the nine manufacturers and a detailed evaluation was performed.

2.3.2 Evaluation Criteria and Procedure

The selection of the test emulsifier was based on a decision matrix comprised of fourteen (14) evaluation parameters or criteria. Of these fourteen criteria, seven (7) were selected for use in a weighted scoring system which resulted in a final point score total to summarize the matrix evaluation. A final selection requirement was the demonstration of emulsifier operation and guaranteed emulsion quality at the U.S.C.G. Academy boiler facility as a condition of acceptance and payment.

The weight scoring system was based on the most significant parameters in the matrix and weighting was accomplished in accordance with criteria importance, relative to the requirements and objectives of the test program. The elements in the evaluation which were weighted were:

- Emulsion Droplet Size, Distribution and Stability
- Number of Boiler Installations (Experience)
- Documented Field Test Data
- Cost of Complete System
- Power Consumption
- Water/Fuel Ratio Range
- System Configuration Offered (complete system or components only)

The remaining evaluation criteria were:

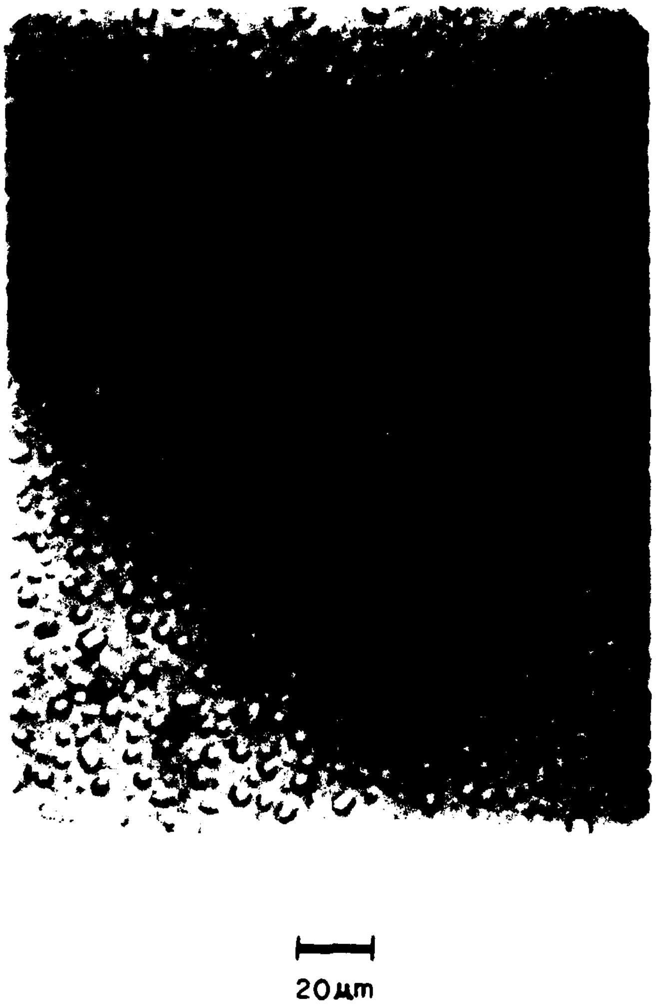
Chemical or Additive Requirements
Recirculation Requirements
Continuous or Intermittent Operation
Guarantee/Warranty
Delivery
Claimed Boiler Efficiency Improvements
Availability of Emulsion Quality Test Data

The nine manufacturers were evaluated on the basis of the foregoing criteria. The weighted point score total, in conjunction with the remaining evaluation criteria analyses results, along with emulsion quality verification by on-site demonstration resulted in the procurement of a Folland Emulsion Fuel System for the test program. A discussion of the major evaluation criteria relative to the Folland ST4 series system follows.

* Emulsion Quality - the most important factor, and the most heavily weighted in the evaluation was the quality of the emulsion produced by the device. Emulsion quality considerations included water droplet size, distribution, and stability of the emulsion. With respect to droplet size, extensive research and laboratory and field tests have shown that the maximum effectiveness of the water is achieved when water droplets are in the 2-5 micron range. Therefore, an objective of water droplet size of 2-5 micron was established for this program. The following maximum droplet size and distribution requirements were established. Water droplet size in the emulsion was to be 100 percent less than 10 microns with 70 percent less than 6 microns.

  The Folland unit test data indicated compliance with this criteria. In an actual performance demonstration at the test facility the emulsion quality was within guarantee limits. A photomicrograph of the emulsion produced is shown in Figure 2-4.

FIGURE 2-4



500x Photomicrograph of 5% Water-In-Oil Emulsion Sample
For Folland Emulsifier Acceptance Test
February 20, 1981

* Previous Application Experience - this factor included an assessment of the number of units installed in boiler applications, the availibility and content of test data from these applications, and the operating performance of the unit (availability, reliability, maintainability, etc.). Only three of the manufacturers had in excess of twenty (20) units installed. The remaining six (6), of which Folland was one, had less than thirteen (13) units in the field at the time of the evaluation. Folland's data from field test experience was very good. Some problems however had been experienced with the system's fuel pump reliability but service had been responsive and corrective action was in progress relative to the pump problem. Overall, Folland scored above the average in this category.

* Constant Input-Variable Output Design - the ability of the selected emulsifier to maintain a high quality emulsion over the entire fuel flow range of the boiler was an important consideration, especially for this test application where there are wide swings in steam demand. There are no requirements for recirculation with the Folland unit and, as compared to a continuously on-line system, emulsion quality is constant. While there were some concerns relative to reliability of intermittent or cycling type systems, they were not significant enough to counter the positive benefits of the constant high quality emulsion production.

* Additional Considerations - the following commments summarize the results of the evaluation relative to the other criteria considered.

  - The Folland unit was offered as a complete prepackaged system for easy installation and with minimal interface requirements.

  - Power consumption for the selected unit, while not the lowest of those considered, was lower than the majority.

  - The cost of the Folland system, while higher than most of

the other emulsifiers considered, was not of such a magnitude to significantly impact its score in this category.

- Equipment delivery and guarantee terms for the Folland system were only exceeded by one other manufacturer.

In summary, and as previously stated, the combined weighted scores, in conjunction with the other evaluation criteria and the demonstration of guaranteed emulsion quality, made Folland the selected unit for this test program.

2.4 Boiler Cleaning, Tuning and Repair

At appropriate points during the program the test boiler was cleaned and tuned; and repairs were performed, as required. The specific times when this work was performed are identified below. Also provided is the rationale for each instance.

* Between Preliminary Tests and Pre Long Term Neat Oil Tests: The preliminary tests determined the "as is" efficiency level of the test boiler. One of the objectives of the next set of tests, Pre Long Term Neat Oil Tests, was to identify the amount of efficiency recoverable through cleaning and repair of the boiler and proper tuning of the combustion control system.

  Further, this point essentially marked the start of the long term test period. As the test objectives included the determination of the boiler fouling rate and efficiency degradation rate, a cleaned and tuned boiler was necessary at the commencement of the long term test period.

  Finally, the efficiency and emissions levels determined with neat oil on the cleaned and tuned boiler established the "baseline" performance data against which all other test data was to be compared.

* Between Long Term Neat Oil Tests and Long Term Emulsified Oil Tests:
  At this point the cleaning, tuning and repair procedures were

performed to establish a comparable start condition for the long term emulsified oil test. Since a repeat of neat oil baseline tests was performed at this time, it was necessary to return the boiler to its optimum condition.

* After Completion of the Post Long Term Emulsified Oil Tests: At this point all emulsified oil testing had been completed. To verify that there had been no unnoted shift in boiler performance, final baseline neat oil tests were conducted. This necessitated again returning the boiler to a clean and tuned condition.

2.4.1 Boiler Inspection

Periodic detailed boiler inspections were performed on the test boiler. These inspections included assessments of both the boiler firesides and watersides. Additionally, external inspections of the boiler were conducted to, for example, assess boiler cleaning conditions and the condition of other important items such as forced draft damper control linkage. Inspections were conducted both before and after cleaning and repair functions with the following being primary objectives.

* Identification of malfunctioning or deteriorated equipment requiring repair or replacement to return the test boiler to its optimum baseline condition.

* Post cleaning and repair inspections were conducted to verify that all repairs and cleaning procedures were adequately performed.

* To provide a documented qualitative assessment of boiler fireside fouling rate for both the neat oil and emulsified oil long term tests. Boiler inspections were performed at the beginning (clean boiler) and at the end (dirty boiler) of each test period.

Previously presented Table 1-1, Summary of Major Program Events, identifies when boiler inspections were performed during

the program.

2.4.2 Boiler Cleaning

At each scheduled cleaning, the test boiler firesides were thoroughly cleaned by the following described procedures.

(1) All tubes and heat transfer surfaces were steam lance cleaned.

Where required, surfaces were wire-brushed to remove any areas of scale not removed by steam lancing.

The firesides of the boiler were then thoroughly sprayed with a liquid carbon destructor to assist in the removal of any remaining hard scale, in unaccessible areas, for example, not taken care of in the first two cleaning steps. This chemical promoted the burning-off of scale when the boiler was fired.

Cleaning of the boiler waterside was only performed once during the program. This procedure was performed at the beginning of the program between the Preliminary and Pre Long Term Tests. Subsequent waterside inspections indicated consistently clean boiler waterside conditions and therefore only hose washing was performed. The initial waterside cleaning was accomplished by hose washing of the drums and tubes to remove loose mud and scale followed by acid cleanings and final flushing of the tubes and drums.

2.4.3 Boiler Repairs

At each boiler cleaning interval, all necessary boiler proper and support equipment repair, replacement and/or adjustments were performed. These repairs included sealing of boiler casing leaks, repair of brickwork and refractory, and repair, replacement or adjustment of burner register components. Virtually all repair requirements throughout the program were considered very minor in nature. In only the following case could they have been referred to as major. However, even in that case there was no resulting impact on test performance or data validity.

During the boiler inspection performed at the completion of the neat oil long term test, the knee walls of the test boiler exhibited rather severe cracking and buckling. This condition had been noted during previous inspections and repairs were made to the cracks and new refractory caps were installed at that time.

However, deterioration of the brickwork had progressed to the point where replacement of the walls was considered prudent to preclude a serious failure during the upcoming long term emulsified oil test period. Therefore, the knee walls were removed and new walls were installed. As previously stated, this was a side wall brickwork repair and did not alter the boilers performance characteristics as, for example, a replacement of the front (burner) wall might have.

It should be stated that this conditon did not result from the effects of any tests which had been conducted in this program. This condition was considered to be attributable to the total accumulated operating hours of the boiler with the repair requirement unfortunately being only coincidental with the conduct of this testing.

2.4.4 Boiler Tuning

Upon completion of each boiler cleaning and repair procedure a complete tuning of the test boiler combustion equipment and control system was performed. Specifically, these tunings were accomplished:

* Prior to Pre Long Term (Baseline) Neat Oil Tests
* Prior to Interim Baseline Neat Oil Tests
* Prior to Final Baseline Neat Oil Tests

To assure that the set up of the test boiler was optimized relative to efficiency and operating requirements, technical representation from the Bigelow Boiler Company, Peabody Engineering and Westinghouse (Hagan Combustion Control) were present at the first boiler tuning sequence. At this time all manufacturers'

inputs were considered and, in all cases, problem areas were satisfactorily resolved. The following paragraphs highlight the major tuning activities.

Normal operating practice, relative to burner size selection, had been to use a number of different sized tips over the boiler operating range. This procedure resulted in the use of appromimately four different tips from minimum to maximum boiler loads. The proper procedure however is the use of a single burner tip size over the entire operating range of the boiler. This procedure permits a single optimum setting of the burner diffuser/tip and diffuser/throat distances which is not possible with multiple tip size operation. Further, single tip size operation permits more optimum cam settings on the combustion control system.

On the basis of the manufacturer's burner curves and the anticipated boiler loading profile, a 116-82 tip size was selected for use during the test program.

After selection of the burner tip size, the correct tip to diffuser distance was set. The boiler was then fired at its maximum firing rate using two 116-82 tips and the diffusers were positioned in the burner throats for optimum flame condition. Reference marks were made on the burner tubes to permit repeatable set up.

The boiler was then operated through its entire range of fuel oil pressures and checks by both the burner and combustion control representatives confirmed proper operation.

The combustion control system was then adjusted to provide minimum permissible oxygen levels over the boiler operating range. The optimum level was that which corresponded to a twenty percent (20%) opacity reading. Specific operating instructions, for the combustion control and the O_2 trim system, including curves and graphs, were developed for use by the boiler operating personnel to achieve consistent and optimum O_2 levels.

Additionally, any worn component parts of the burner and combustion control system were replaced. These included, for example, burner tips, springs, cams, etc.

Finally, a number of boiler and auxiliary system alarm and trip settings were adjusted to more reasonable levels to eliminate nuisance trips experienced during the preliminary boiler tests.

During all subsequent tuning sequences the above actions, where applicable and required, were performed.

2.5 Efficiency Testing

In order to accurately measure the improvements in efficiency obtained through cleaning, tuning, repair and proper operation of the boiler and those attributable to water in fuel emulsion firing, a series of controlled efficiency tests were performed. Further, these tests were also conducted to quantify any loss in boiler efficiency attributable to boiler fouling during the long term test periods. These efficiency test series are identified as follows with a discussion of the objectives associated with each test.

* Preliminary Neat Oil Tests
  Efficiency measurements were made with the test boiler in an "as is" condition prior to any cleaning, repair, tuning or in operating procedure modifications. The test objective was to determine the efficiency at which the boiler was typically operated and thereby identify the start point for future efficiency improvement.

* Pre Long Term Neat Oil Tests
  These efficiency tests were performed after boiler cleaning, repair and tuning with the recovered efficiency levels being attributable to these actions. The boiler efficiency levels determined during these tests represented the efficiency baseline level against which boiler efficiency levels when firing emulsified oil were compared.

  Additionally, this efficiency test data represented the

starting levels for the long term test period. Comparison of the data with the efficiency measurements taken at the end of the long term test resulted in identification of the level of performance degradation over the test period.

* Post Long Term Neat Oil Tests
  At the completion of the long term test period a series of efficiency tests were conducted. As previously mentioned, efficiency values of this test were compared with pre long term test data to determine the effect of boiler fouling in performance degradation.

* Interim Baseline Neat Oil Tests
  After boiler cleaning, repairs and tuning, an efficiency test series was performed to verify that no shift in boiler performance had occurred and that the boiler had been returned to a condition the same as at the start of the neat oil long term tests. This data was also considered the base data for the emulsifier optimization tests.

* Pre Long Term Emulsified Oil Tests
  The efficiency levels measured at this point provided the amount of efficiency improvement attributable to emulsion firing. This determination was a result of a comparison of this data and both the pre long term neat oil test data and the interim baseline test data. Secondly, the measure efficiency levels represented the start point for the long term emulsified oil test.

* Post Long Term Emulsified Oil Tests
  At the completion of the long term emulsified oil tests, the obtained boiler efficiency levels provided the measure of performance degradation resulting from boiler fouling during the long term test period.

* Final Baseline Neat Oil Tests
  After the final boiler cleaning and tuning, baseline neat oil

efficiency measurements were made to again confirm no major shift in boiler performance during the previous long term test period.

2.5.1 Efficiency Test Methodology

Boiler efficiency determinations were made in accordance with the Abbreviated Efficiency Test Method of PTC 4.1 of the American Society of Mechanical Engineers Power Test Codes for Steam Generating Units. Efficiencies were calculated by both the input/output and the heat loss methods. The Abbreviated Efficiency Test Method considers only the major losses and only the chemical heat in the fuel as input. It ignores the minor losses and heat credits. These heat losses (moisture in air, heat in atomizing steam, sensible heat in fuel, primary air fan power and heat supplied by moisture in entering air) have a minor impact on the calibrated efficiencies. Also, as program conclusions are based on comparative analyses of the efficiency tests, with the minor heat losses and credits being similar for each test series, their impact is further minimized.

Efficiency tests were conducted over the entire boiler operating range from approximately 20% boiler load to 100% boiler rating. For each test series, efficiency measurements were taken at eight (8) boiler load levels. Every boiler efficiency test was of a minimum four (4) hour duration.

In order to achieve the higher boiler load levels when actual steam demand of the facility was minimal, a steam venting system was installed on the test boiler. Hand regulation of the system permitted venting of steam to the atmosphere via mufflers to obtain the desired boiler load level.

During the course of efficiency testing, boiler parameters required by PTC 4.1 were logged every 15 minutes. Data logging was performed both manually and by the automatic data logger. The data logger was programmed to record every 15 minutes with the 15 minute average of the parameter being the value logged. The parameters being monitored and recorded by the data logger were:

fuel flow (gpm)	feed water flow (gpm)
fuel temperature (^{o}F)	feed water temperature (^{o}F)
fuel pressure (psig)	feed water pressure (psia)
fuel viscosity (SSU)	furnace draft ("H_2O)
steam calorimeter temp. (^{o}F)	flue gas temperature (^{o}F)
steam flow (LB/HR)	flue gas O_2 content (%)
steam temperature (^{o}F)	combustion air temp. (^{o}F)
steam pressure (psia)	

A sample data logger sheet is provided in Appendix B.

Fuel samples were obtained for each efficiency test series. Fuel oil heat content and specific gravity values for meter correction were used in the efficiency calculation. All efficiency calculations were made with a calculator programmed in accordance with the equations in PTC 4.1.

2.6 Boiler Emissions Testing

Concurrent with the performance of efficiency tests, boiler emissions testing was conducted. The following analyses of flue gas were performed.

* Measurement of content of carbon dioxide (CO_2), carbon monoxide (CO), oxygen (O_2) and nitrogen (N_2), by difference. These parameter values were used to calculate excess air during the efficiency tests.

* Measurements of particulate and oxides of nitrogen (NO_x) emission rates. These measurements were made during selected efficiency tests to determine the reduction in these emission rates when firing emulsified fuel oil as compared to neat fuel oil.

The flue gas sampling location for the test boiler is shown in Figure 2-5. As indicated, the sampling cross-section is situated 9'6" downstream and 7'6" upstream from the nearest flow disturbances. This location meets the minimum requirements for the determination of volumetric flow rate and isokinetic sampling for

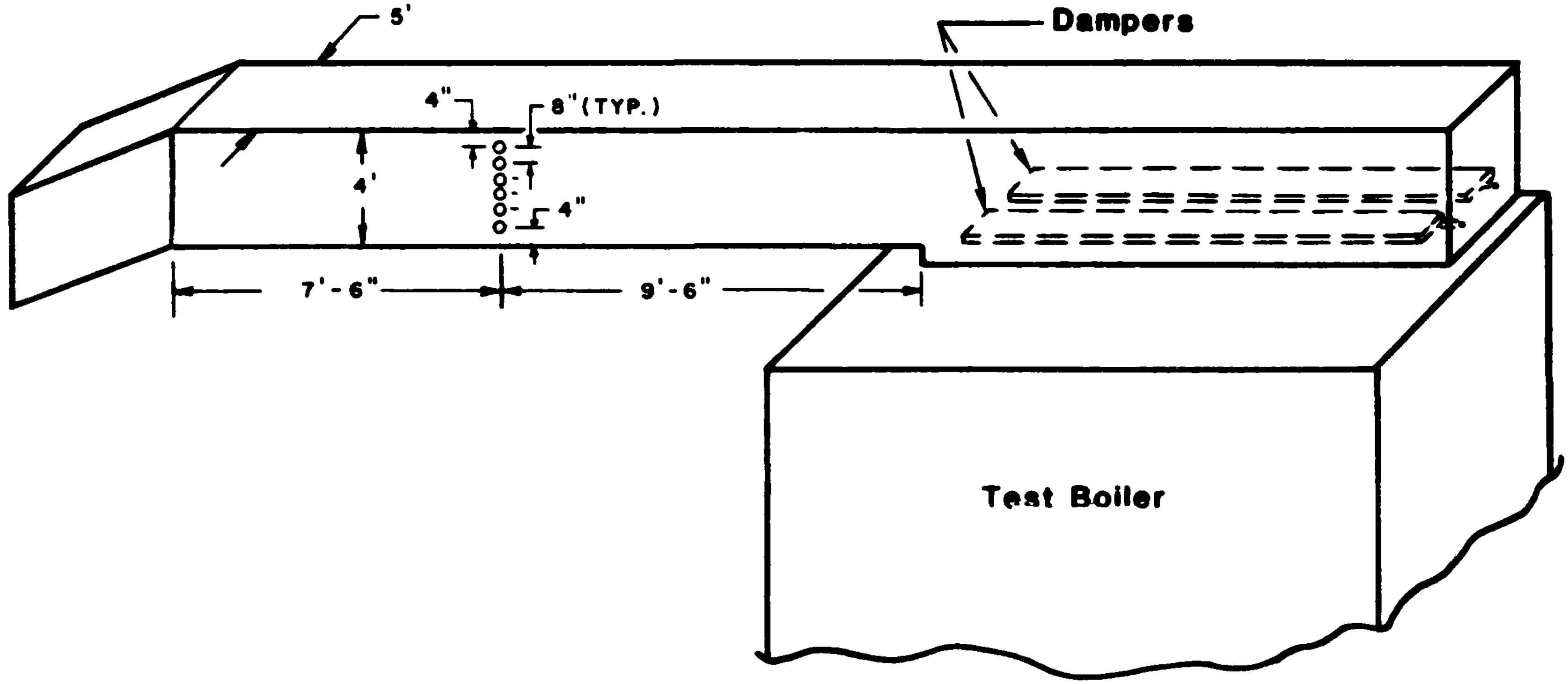


Figure 2-5

Flue Gas Sampling Location

particulate emissions according to EPA Methods 1 and 5[1]. The sampling cross-section and sampling points are shown in Figure 2-6.

2.6.1 Measurements of CO_2, O_2, CO and N_2

Measurement of these parameters was performed during every efficiency test conducted in the program. Integrated bag samples were collected during each half hour of each four hour efficiency test period. Filtered and dried samples of the flue gas were collected in Tedlar™ bags, using the integrated bag sampling apparatus described in EPA Method 3. The contents of each bag was analyzed for CO_2, O_2 and N_2 with an Orsat and for CO with an Ecolyzer Model 2800. The Ecolyzer uses an electrochemical method to measure the CO concentration. The Ecolyzer was fitted with an SO_2 scrubbing column to remove SO_2 which is an interference. The Ecolyzer was calibrated during each efficiency test with a gas having a known CO value. The Orsat was checked daily against the ambient air to insure accurate O_2 readings. All of the integrated gas samples taken for the tests were extracted from the mid-point of port 4, shown on Figure 2-6.

2.6.2 Measurement of Particulate and NO_x

Particulate mass concentration was measured in accordance with EPA Reference Methods 1 through 5. The number of sampling points, 48, and location of sampling points was determined from the distance between upstream and downstream flow disturbances per Method 1. The sampling time for each traverse point was three (3) minutes for a total sampling time of 144 minutes per test. To reduce the time for testing, the duct was sampled with two Method 5 trains simultaneously.

The velocity and volumetric flow rate of the flue gas were measured with an S-type Pitot tube, as specified in Method 2. The moisture content of the flue gas was determined by condensation as described in Method 4 and 5. The particulate concentration in the flue gas was determined by extracting a sample stream of the flue

1 Appendix A - Reference Methods, Title 40, Chapter 1, Part 60 - Standards of Performance for New Stationary Sources, Federal Register, Vol. 36, No. 247, December 23, 1971 and as revised in Vol. 42, No. 160, August 18, 1977.

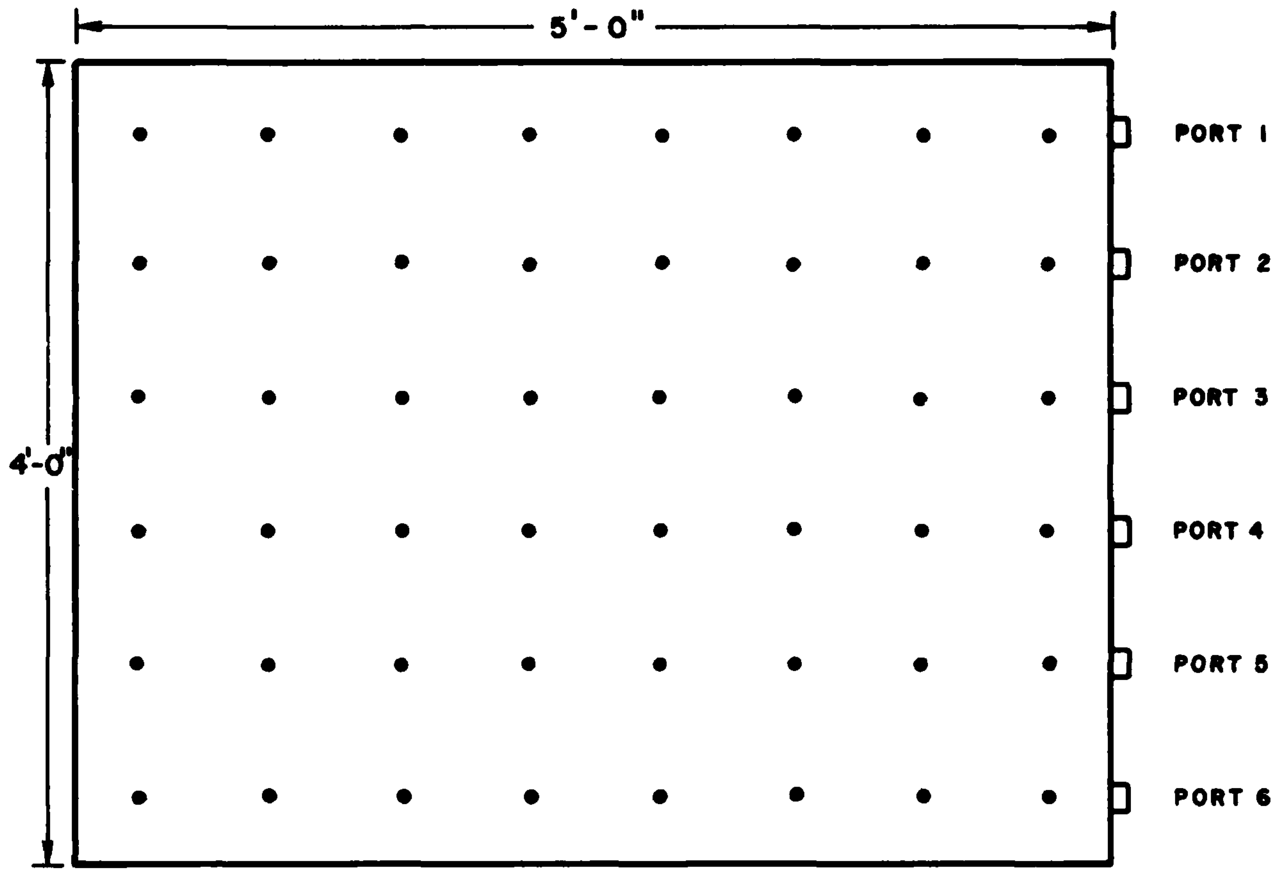


Figure 2-6

Boiler Duct Cross Section at Flue Gas Sampling Point

isokinetically (velocity in sampling nozzle equals velocity in duct $\pm$ 10%) and removing the particulate from the stream by passing it through a glass fiber filter. The temperature of the extracted stream was maintained at $248^{o}F \pm 25^{o}F$, as specified in EPA Method 5 to prevent condensation in the sampling probe or on the filter. The sample stream minus the particulate was then passed through a condenser and silica gel to remove all the moisture. The dry, particulate-free sample was pumped through a dry gas meter which measured the volume sampled and through a calibrated orifice meter which measured the instantaneous sample flow rate. The weight of particulate collected was determined gravimetrically from the tared filter and beaker in which the probe was washed with acetone. The samples were dried in an oven and desiccated to constant weight. The concentration was calculated from the weight of particulate collected and the volume of dry sample gas corrected to standard conditions. The mass emission rate in pounds per million BTU fired was calculated from the particulate concentration, the cubic feet of stack gas per million BTU based on a stoichiometric calculation from the fuel analysis and the percent O_2 in the flue gas.

Complete sampling train calibrations (Pitot tubes, thermocouples, dry gas meter, orifice meter and nozzle) were performed prior to and after each test set. These calibrations of flow and sample volume measurement instruments were done with NBS traceable standards.

The NO_x concentration was monitored during each particulate test using a Monitor Lab Model 8430 NO_x Monitor. The monitor first thermally converts all the NO_x to NO, then measures the NO by chemiluminescence. The sample was extracted from the middle of the duct through sampling port number 4, as shown in Figure 2-6. The sample stream was filtered and dried, using a Drystack Model SC-10 sample conditioner, before entering the monitor. The NO_x concentration was averaged for each half of each particulate test. The average concentrations were used with fuel analysis and percent

O_2 to perform a stoichiometric calculation of pounds NO_x per million BTU fired.

Particulate and NO_x measurements were made during the following noted tests:

* Pre Long Term Neat Oil Test
* Post Long Term Neat Oil Test
* Pre Long Term Emulsified Oil Test
* Post Long Term Emulsified Oil Test

During each test period the measurements were made at two (2) boiler load levels; a low load (approximately 35% of boiler rating) and a high load (approximately 98% of boiler rating). At each of these boiler load points, five (5) repetitive measurements of particulate and NO_x were made. This five test criteria was established prior to the start of any testing and was based on the ninety percent (90%) probability of detecting a twenty percent (20%) change in emissions when the measurement method has a ten percent (10%) variability in precision[2]. The method for particulate measurement has been shown to have variability in precision from collaborative testing[3]. While this five test criteria appears to be somewhat conservative in light of the actual test results, it was consistent with the overall program objectives of obtaining accurate and credible data within practical limitations.

2.7 Long Term Boiler Tests

In order to assess the impact of water in fuel emulsion firing on boiler fouling and performance degradation rates as compared to neat oil operation, two long term boiler tests were performed. One test was conducted using neat oil and the second was performed with emulsified oil. In addition to measuring and comparing boiler performance degradation, several other objectives were included in the long term testing. These were to assess any changes in mainte-

[2] Natrella, M.G., Experimental Statistics, National Bureau of Standards Handbook 91, August 1963.

[3] Midget, M.R., "Validating New Source Performance Standards," Environmental Science & Technology, Vol. 11, No. 7, pp 655-659, July 1977.

nance requirements resulting from emulsified oil operation and to identify any adverse boiler tube corrosion or erosion conditions as a consequence of water in fuel emulsion firing.

Each long term test period was of approximately the same dura-ation, eight and one-half (8½) months for the neat oil versus nine and two-thirds (9-2/3) months for the emulsified oil test. In order to obtain directly comparable test data, the long term test periods were scheduled to:

(1) Have approximately equivalent amounts of fuel oil consumed during each long term test period (479,980 gallons for neat oil versus 491,840 gallons for emulsified oil test).

(2) Experience comparable firing rate profiles for each test period. It was considered undesirable to have, for example, one test conducted totally at low firing levels (summer time) and the second test conducted only at high firing rates (winter time).

The following subsections provide the details of the long term testing.

2.7.1 Efficiency and Emissions Degradation

At the start of each long term test period, neat oil and emulsified oil, the boilers were in a cleaned and tuned condition. Complete efficiency and emissions measurements were taken to establish starting point levels to be used in a comparison of test end point efficiency and emissions levels. The difference between the start and end point levels represented the amount of performance degradation. A comparison of the neat oil performance loss and the emulsified oil performance loss was made to determine any benefit attributable to water in fuel emulsion firing.

During the course of the long term test periods, boiler operating parameters were monitored and logged every four (4) hours. The data was logged manually by the watchstander and automatically by the data logger. The values logged by the data logger represented the four (4) hour average for each parameter. Additionally, the

data logger was programmed to record parameters during the four (4) hour period if the boiler experienced a load swing in excess of 4000 LBS/HR.

The data collected was reduced and analyzed to provide a daily "efficiency ratio" of steam generated to million BTU's fired. The objective of this analysis was to determine the efficiency loss trend as a function of boiler fouling and time. This data proved to be of minimal, if any value and no meaningful conclusion could be drawn. It is believed that the test boiler's unique load profile (daily and seasonal) provided considerably more variability in the "efficiency ratio" than the fuel fired.

Boiler inspections were performed at the start and completion of each long term test period. This procedure provided a visual assessment of the boiler fireside condition to permit a comparison of neat oil and emulsified oil fouling rates. Further, these qualitative assessments provide verification of the quantitative analysis of efficiency loss as there is a direct correlation between boiler cleanliness and efficiency level.

2.7.2 Boiler Tube Corrosion/Erosion

In order to assess the impact of water in fuel emulsion firing and boiler tube corrosion and erosion as compared to neat oil firing, metallurgical analysis of tube materials was included as part of the long term boiler testing.

In each test, neat oil and emulsified oil, boiler tube test sections (3" long x 1.2" wide) were welded into boiler tubes located where maximum erosion and corrosion was expected to occur. Material test samples were located in exactly the same locations for each test. In each case six (6) tubes in the boiler's number 1 tube bank and three (3) tubes in the number 14 tube bank were fitted with test pieces. The samples in the number 1 tube bank were expected to experience the maximum potential for erosion, as this bank experiences maximum gas temperature and velocities. Test samples were installed approximately 45 degrees from the axis of normal gas flow and directly faced the flow.

In the case of the test samples placed in bank number 14, these were expected to show the greatest effect of corrosion as gas temperature is at a minimum in this area. The test samples were installed on the top side of each tube facing the boiler outlet damper.

Prior to the installation of the test sample, specific gravity measurements and metallographic and spectrographic analyses on the material were performed to establish a test baseline. The thickness of all specimens was measured prior to installation in the boiler. Upon removal of the tube samples at the completion of the long term tests, the following analyses comprised the testing procedure to provide sufficient data for a comparative analysis between neat oil and emulsified oil firing.

* Specific gravity measurement
* Visual characterization of deposits in tube samples
* Semi-quantitative spectrographic analysis of tube sample deposits
* Metallographic analysis to determine damage and deterioration at the grain boundary
* Measurements of thickness and specific gravity after cleaning test samples

As a consequence of procedures employed in removal of the first set of test samples, the samples suffered damage necessitating modification of the foregoing test procedures. The results of these material analyses are presented in Section 4.1 of this report.

2.7.3 Maintenance Considerations

The long term testing also included an assessment of the impact of water in fuel emulsions on periodic maintenance requirements. These maintenance actions included what can be considered as routine operational items, such as soot blowing, as well as longer interval periodic maintenance requirements, such as boiler fireside cleaning.

In order to assess any change in soot blowing requirements

(extended intervals) when operating on emulsions as compared to neat oil, standard operating procedures were established.

These procedures were based on the boiler manufacturers recommendations that tubes should be blown when the stack temperature exceeds clean boiler stack temperature value by 25^{o}F. Therefore, this 25^{o}F differential was established as the criteria for soot blowing. As an operating guide for use by the boiler room watchstanders, a curve of stack temperature versus boiler load was developed using data obtained from cleaned and tuned boiler efficiency tests. During both the neat oil and emulsified oil long term tests, soot blowing frequency was logged. A comparative analysis was then made to determine if emulsified oil operation permitted longer intervals between soot blowing requirements.

Finally, on the basis of the boiler inspections performed at the end of each long term test period, an assessment was made relative to boiler fireside cleaning requirements for an emulsion fired boiler as compared to a neat oil fired unit. Specifically, the potential for extending fireside cleaning intervals was of prime consideration. The condition of the boiler fireside (degree of tube fouling, condition of brickwork, etc.) was the primary factor used in this assessment.

2.8 Emulsifier Optimization Tests

Prior to the start of any efficiency and emissions testing using water in fuel emulsions, a series of emulsifier optimization tests were performed. The objective of these tests was to identify the water/fuel ratio of the emulsion providing optimum boiler operating effiency. The emulsifier had the capability of generating a high quality emulsion with water concentrations up to the 30% level established as a program maximum.

The optimization tests were performed using excess air level and stack opacity as the key test parameters. To identify the optimum ratio, two basic test approaches were taken. The first approach consisted of varying water concentration of the emulsion

while maintaining a constant boiler load and trimming excess air to achieve a 20% opacity level. The second approach involved maintaining a constant water percentage and varying boiler load from about 20% to 100%, again trimming excess air to a 20% opacity indication.

During all testing, combustion control was operated on manual to permit maximum trimming of excess air. Also, sufficient time was allowed at each test point to achieve stable boiler operation. Additionally, between tests, when the water percentage was varied, enough time was allowed to permit two complete refills of the emulsifier receiver to be assured that the correct water/fuel ratio had been achieved.

Upon completion of the optimization testing and selection of the water percentage for the emulsion, the detailed boiler efficiency and emissions tests were conducted (Pre Long Term Emulsified Oil Tests).

2.9 Fuel and Water Analyses

Fuel oil quality was monitored throughout the entire program by means of periodic fuel sample analyses. Additionally, during emulsified oil test periods, the quality of the water used in the emulsification process was also monitored.

2.9.1 Fuel Analyses

Fuel was considered to be one of the variables present in the test program which had the potential of influencing test results. For example, high vanadium fuels, especially when sodium is present, accelerate boiler fouling rates. If, during the test program, it was not known that vanadium and sodium levels in the fuel had varied greatly causing atypical fouling rates and accelerated efficiency degradation rates, then erroneous test conclusions might be drawn as a consequence of that untimely condition.

While strict quality control was considered impractical and would have created a somewhat artificial field test condition,

monitoring of fuel quality was considered essential to the objectives of the program. While extreme quality excursions were not anticipated, nor did they occur, identification of such a situation would have permitted the opportunity to quantify the impact of the fuel in the test data. Therefore, a fuel sample was analyzed for each 25,000 gallons of fuel consumed. The following fuel properties were obtained from the analysis.

Degrees API @ 60^{o}F	Nitrogen %
Specific Gravity @ 60^{o}F	Oxygen %
Heating Value BTU/LB	Sulfur %
Viscosity @ 122^{o}F & 150^{o}F	Water by Distillation %
Ash %	Sodium ppm
Carbon %	Vanadium ppm

Fuel samples were also analyzed at each efficiency test series to provide the required data for the boiler efficiency calculations (e.g., heating value, specific gravity for fuel oil meter correction, etc.). Sample fuel analyses for the neat oil and emulsified oil tests are included in Appendix C.

Finally, during the emulsified oil testing the analyses provided a method of verifying that the proper water percentage was being used in the emulsion.

2.9.2 Water Analyses

Water to the emulsifier was taken from the New London water system. While it was reasonable to assume that water quality from the public system would remain constant, to be assured of this, water analyses were performed routinely throughout the emulsified oil long term test period.

The water was analyzed for the following properties which were considered to have the greatest potential of influencing boiler fouling rates and tube corrosion rates.

Potassium	pH
Calcium	Chlorides
Sodium	

A sample water analysis is provided in Appendix C.

3.0 FOLLAND EMULSIFICATION FUEL SYSTEM

3.1 Principle of Operation

The Folland Emulsion Fuel System is based on the patented "constant input - variable output" principle to provide precise control of the water to fuel oil ratio and emulsion quality over the entire range of output fuel flows.

This control is achieved by means of an automatic cycling valve which is activated by separate high level and low level sensors in the emulsion receiver. When the receiver level reaches the low level sensor, the automatic cycling valve opens, permitting oil and water flow into the emulsifying unit (Barodynamic Resonator) where the emulsion is produced. The emulsion then flows into the receiver. The emulsion flow is always at "constant input" to the receiver when the cycling valve is open. When the receiver level reaches the high level the automatic cycling valve closes and remains closed until the next cycle. The emulsion can be drawn out of the receiver at any "variable - output" rate, depending upon the fuel oil demand of the boiler.

3.2 System Description

As illustrated in Figure 3-1, the U.S.C.G. Academy's fuel oil service pump discharges to the emulsion system (Fuel Oil In) at approximately 150 psig. Delivery pressure is controlled by a back pressure regulating valve (A) . When the emulsification system's automatic cycling valve (B) closes, the pressure of the fuel oil increases causing the back pressure regulator to open and fuel oil to be recirculated back to the oil storage tank.

The source of water for the emulsification system in this test installation is the city water system. Water flows through a filter (not included with emulsion system) then through a strainer (C) into a water tank (D) via a float operated water inlet valve. The water tank and float valve configuration provides an air gap between the city water supply and the fuel oil emulsion system, thus precluding

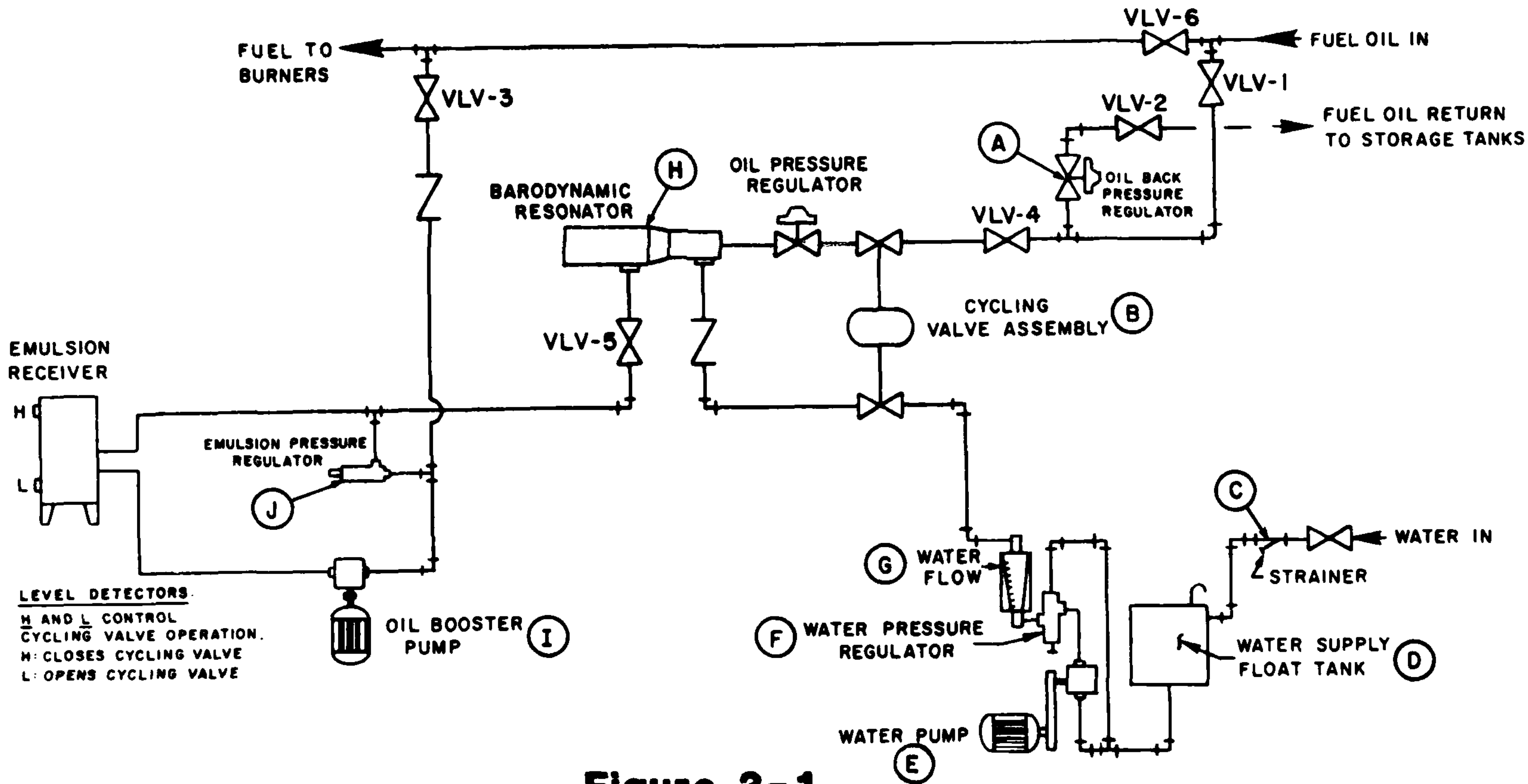


Figure 3-1

Folland ST 4 Series Emulsion Fuel System Schematic

any possibility of oil contamination of the water supply. The water injection pump (E) takes suction from the water tank and boosts the pressure to the required level for injection into the fuel oil stream. The injection pressure is set by a water pressure regulating valve (F) on the pump's discharge. The water pressure is normally set for 20 to 60 psig higher than the fuel oil pressure. The required pressure is dependent on the water/fuel ratio desired and the water orifice size. A rotameter (G) indicates the amount of water being injected into the fuel oil stream. The automatic pneumatically operated cycling valve (B), which is controlled by the high and low level switches in the receiver, controls the flow of fuel oil and water. When the low level switch is activated, the automatic cycling valve (B) will open and allow oil and water to enter the Barodynamic Resonator (H) where the emulsion is produced. The water in oil emulsion then flows into the emulsion receiver. This operating condition is illustrated in Figure 3-2. When the level in the receiver reaches the high level sensor, the automatic cycling valve (B) closes and remains closed until the level in the receiver reactivates the low level switch. Figure 3-3 illustrates this operating mode. The oil booster pump (I) (see Figure 3-1) pumps the emulsion from the receiver to the boiler burner front. The discharge pressure is set and maintained by the emulsion pressure regulating valve (J). The entire emulsion system may be bypassed as shown on Figure 3-4 by changing over three valves which are identified as VLV-1, VLV-3 and VLV-6 on Figure 3-1.

The emulsion receiver is equipped with additional high and low level limit switches in addition to the high and low level control sensors described earlier. These limit switches will shut the emulsion fuel system down in the event of too high or too low a level in the receiver. The receiver is also provided with a means to maintain the emulsion within it at a constant head pressure. The receiver pressure is controlled by pneumatic make-up and bleed. As the emulsion level drops in the receiver, the pressure drops which opens the constant pressure regulating valve on the compressed air supply. When the level in the receiver increases, the pressure rises and the excess compressed air escapes through a relief valve

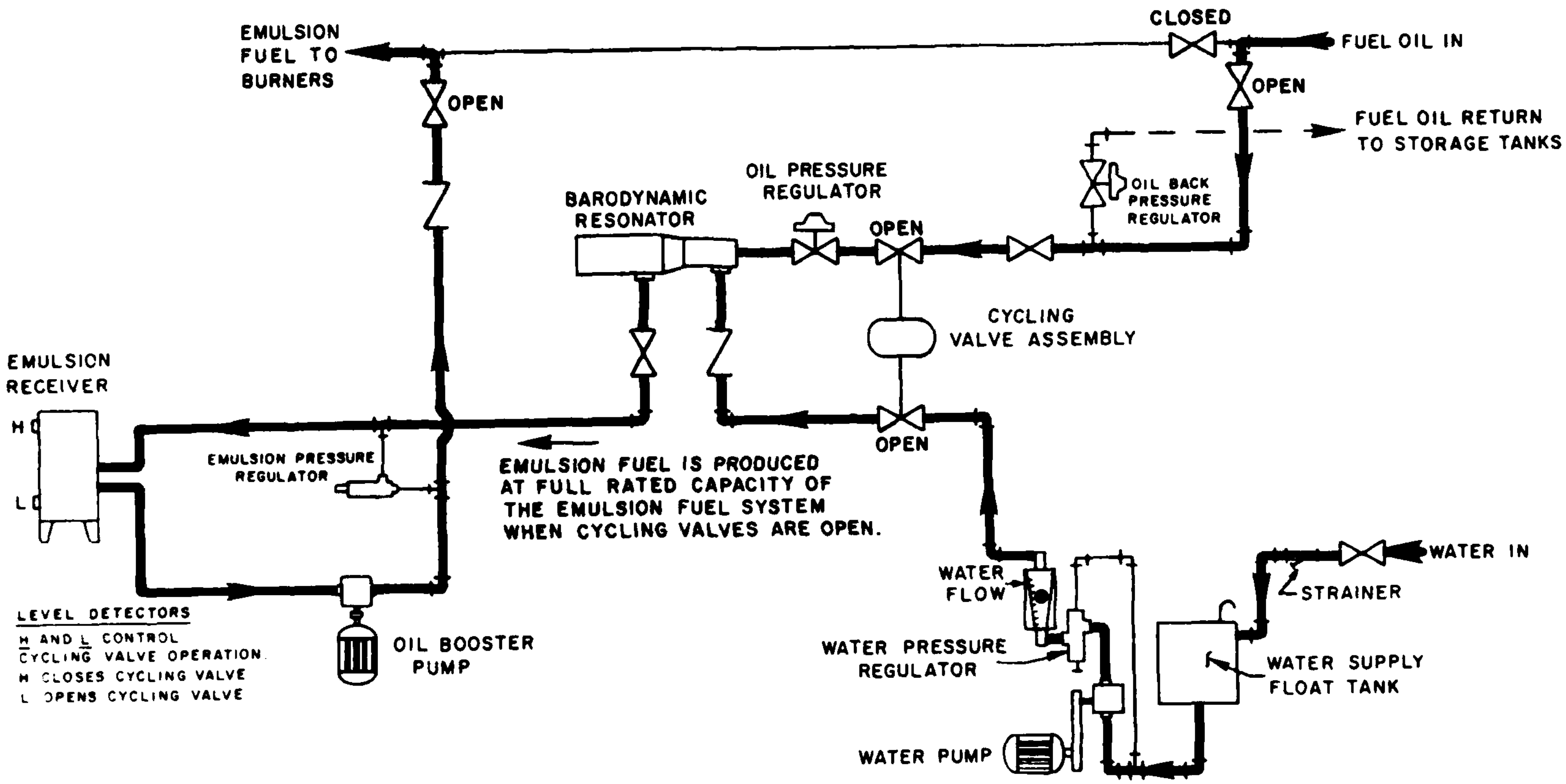


Figure 3-2

Flow Diagram for Folland ST 4 Series Emulsion Fuel System with System Operating, Cycling Valves Open (Receiver Level Down)

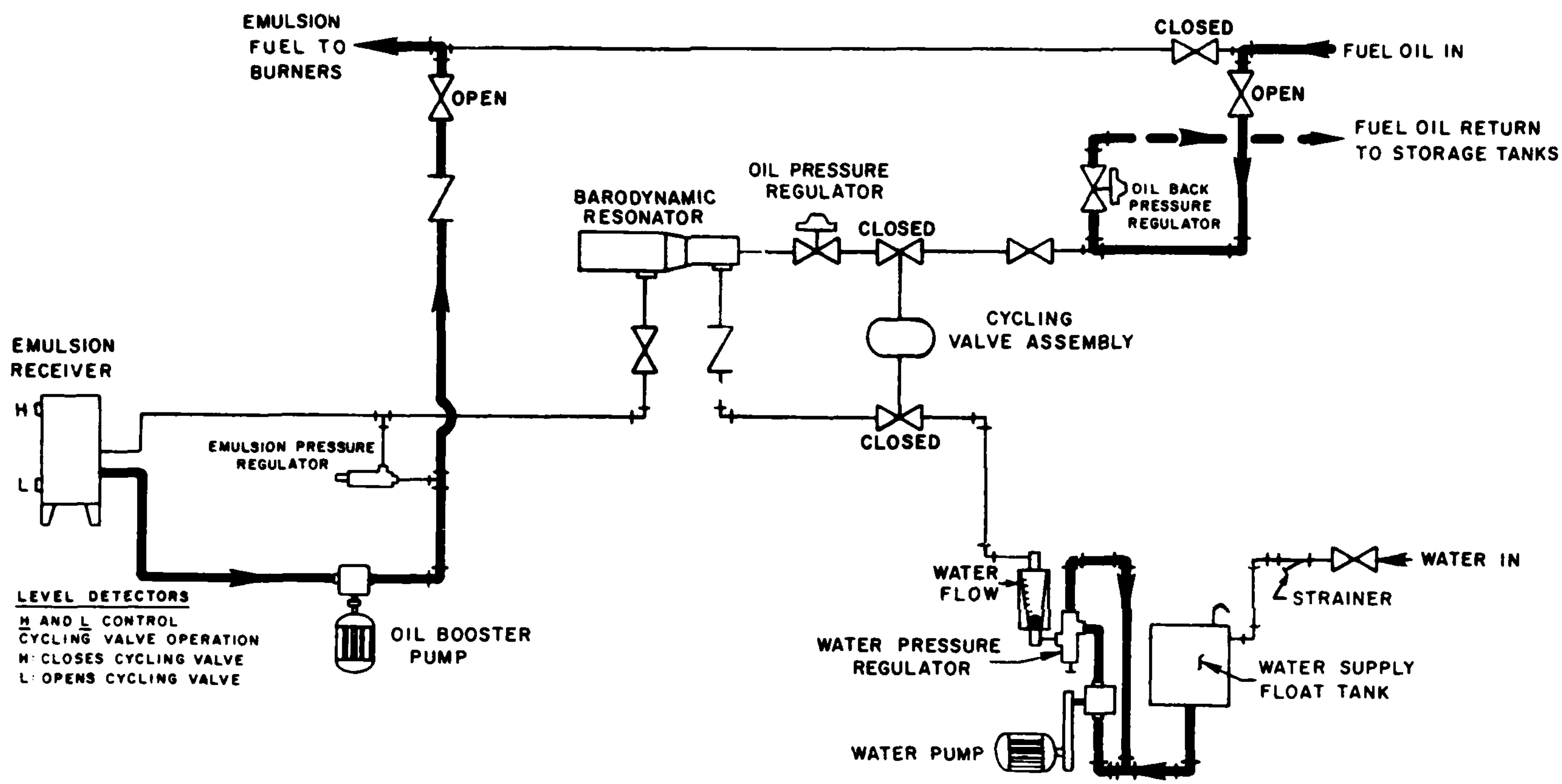


Figure 3-3

Flow Diagram for Folland ST 4 Series Emulsion Fuel System with System Operating, Cycling Valves Closed (Receiver Level Up)

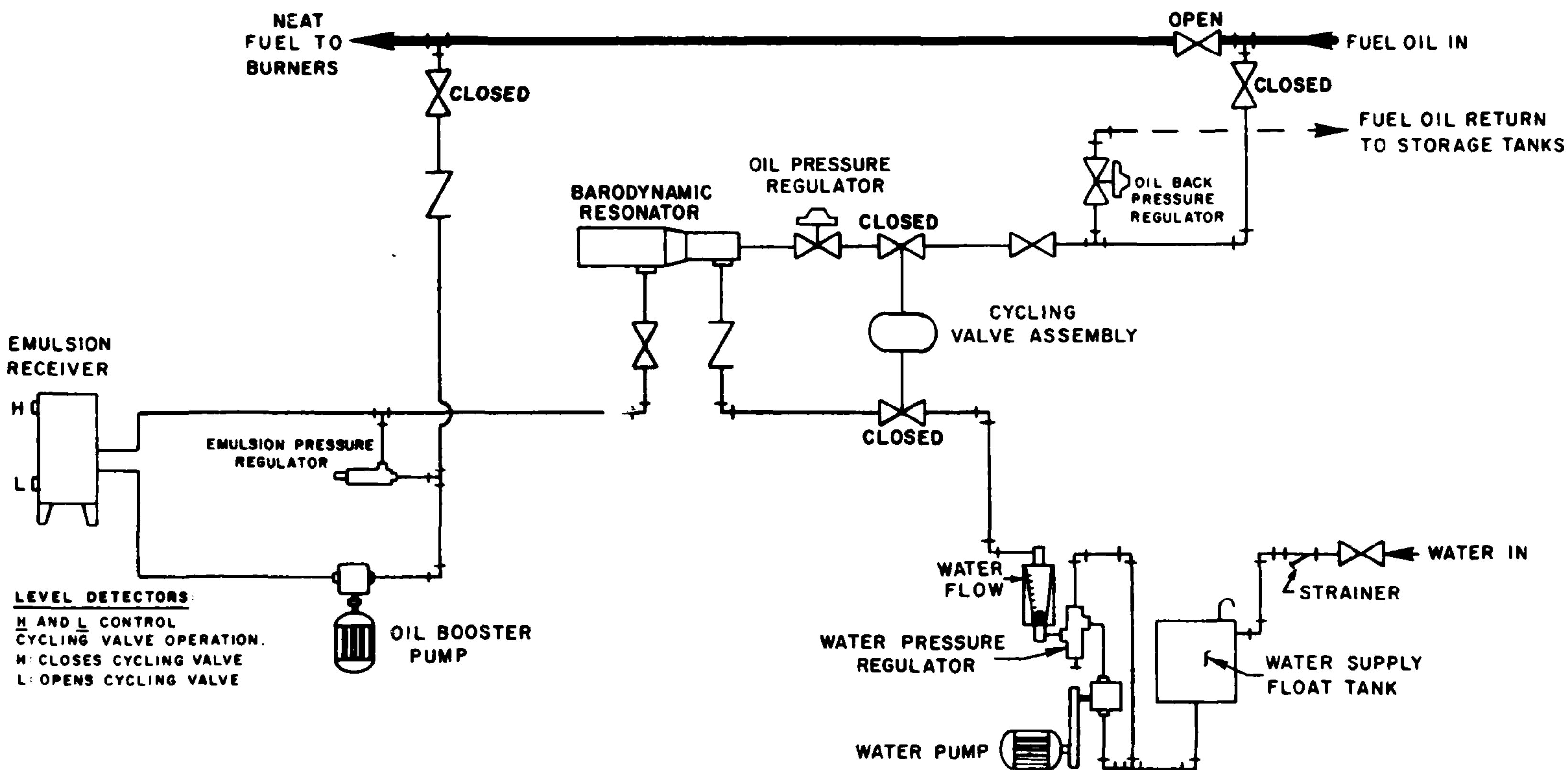


Figure 3-4

Flow Diagram for Folland ST 4 Series Emulsion Fuel System Shut Down

into the vent line. A check valve is provided in the compressed air inlet line.

To ensure that the emulsion system can be restarted after a lengthy shutdown, which could be difficult due to the high viscosity of the cold fuel oil, the receiver is equipped with a thermostatically controlled electric heating element which is set at approximately 130°F.

Built-in sensors will detect abnormal conditions within the system, such as: low fuel oil pressure, high or low receiver level, and low supply tank water level. These sensors are wired to relays which shut the unit down when an abnormal condition exists. Individual indicator lights on the front panel are connected to each sensor. These lights clearly indicate the cause of a shutdown.

3.3 Barodynamic Resonator

The heart of the Folland Emulsion System is the Barodynamic Resonator. It is here that the water in oil emulsion is produced. The Barodynamic Resonator is illustrated in Figure 3-5. The following is a summary of the principles of operation.

Water is injected through an atomizing nozzle (water orifice on Figure 3-5) into the main oil stream and dispersed throughout the oil stream. This dispersion then flows through a swirl-type nozzle where it is atomized and the water particles are broken down further. As the spray leaves the main nozzle, it impinges on the resonant drum. This resonance sends shock waves through the fluid, cavitating the water which breaks the water particles down to their final size in the fuel. The emulsion then exits the Barodynamic Resonator and flows to the receiver.

3.4 Emulsion System Installation

The U.S.C.G. Academy boiler number 3 fuel oil system with the Folland ST 4.150 Emulsifier is illustrated in Figure 3-6. This location allows for direct volumetric, viscosity, pressure and temperature measurements of the fuel supplied to the test boiler.

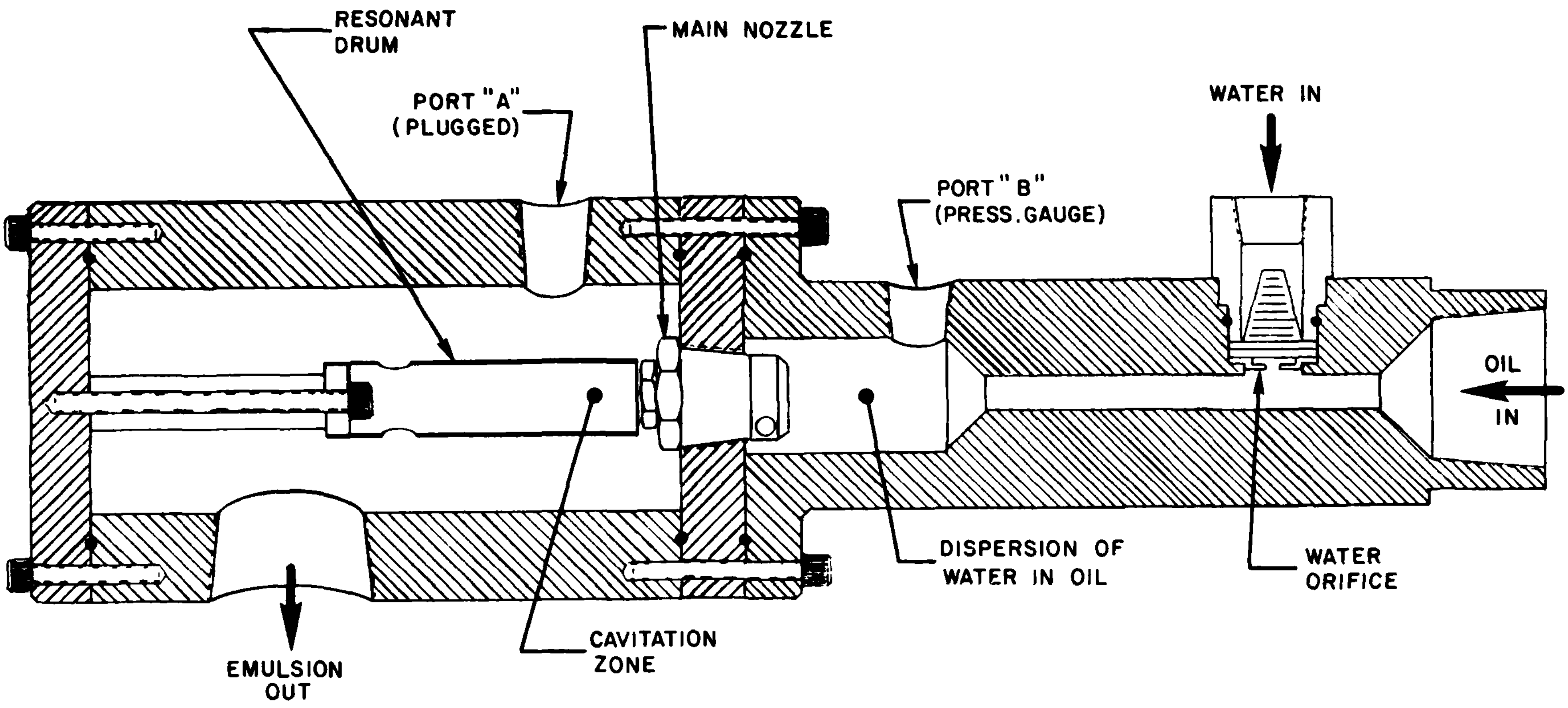


Figure 3-5

Folland Barodynamic Resonator

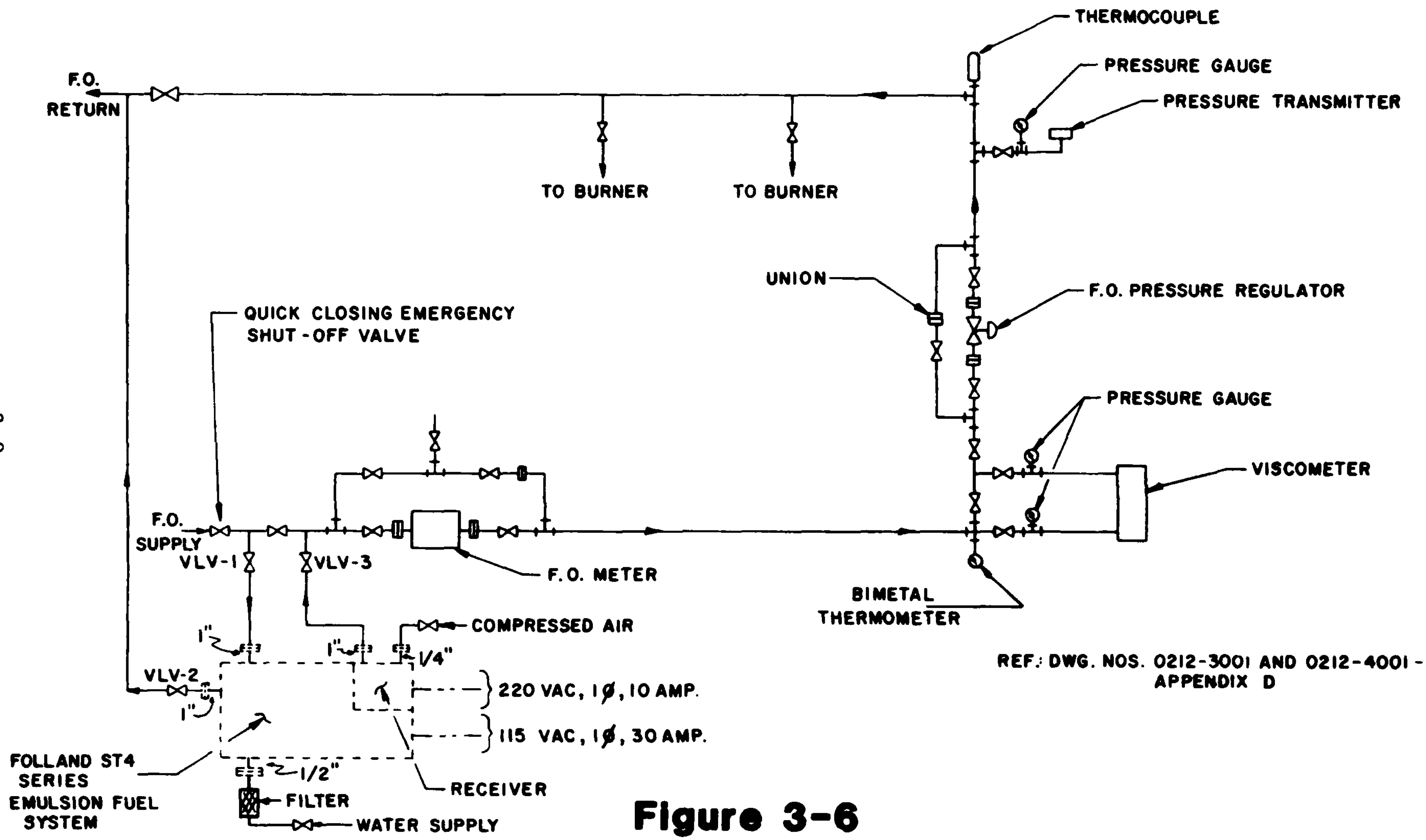


Figure 3-6

U.S.C.G. Academy Boiler No. 3 Fuel Oil System with Emulsifier

The emulsion system is of a two component (skid and receiver) modular design. The skid's dimensions are 44" wide by 36" deep by 39" high. The receiver is 26" wide by 28" deep by 56" high. The complete system weight is approximately 1000 pounds. The system's electrical and mechanical schematics are included in Appendix D.

The Folland ST 4.150 Series Emulsion System is designed for installation with number six (6) fuel oil inlet pressure and temperature of 130-150 psig and 180-200^{o}F, respectively. The other services required are 80 psi compressed air, 20 to 50 psi water, and electrical. The unit's electrical service is normally 440 volt, 3-phase, 60 Hz. However, this was not available at the test site and therefore, the emulsifier was built for 115V AC, single phase and 220V AC, single phase power.

Photographs of the installed ST 4.150 Emulsifier are presented as Figure 3-7 (A through C).

3.5 Emulsion Quality

The quality of the water in oil emulsion produced by the Folland Emulsion System was examined as part of the emulsifier selection process. The emulsion quality was considered satisfactory for the requirements of the test program. Section 2.3.2 provides details of emulsion quality criteria and Folland's performance.

The emulsion quality was checked frequently during the long term emulsified test using a microscope and judged to be suitable. A photomicrograph was taken of a 6% water in oil emulsion sample collected after about seven (7) months of operation of the Folland system and is presented in Figure 3-8. The 20 micrometer reference line on the photo can be used to gauge the size of the water droplets. The results of a count of the particles by size in a 2" x 2" grid on the photomicrograph are presented in Table 3-1. This emulsion indicates a slight change from the initial emulsion (see Section 2.3.2). There is an increase in the number of small water droplet sizes as compared to the distribution in the initial emulsion photomicrograph.

FIGURE 3-7

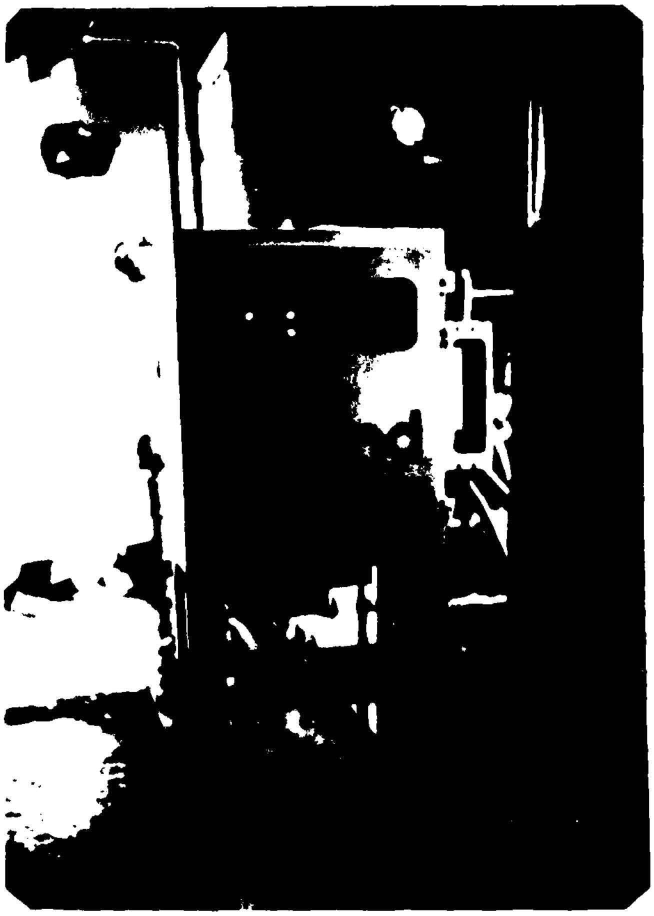


Photo A - Front View

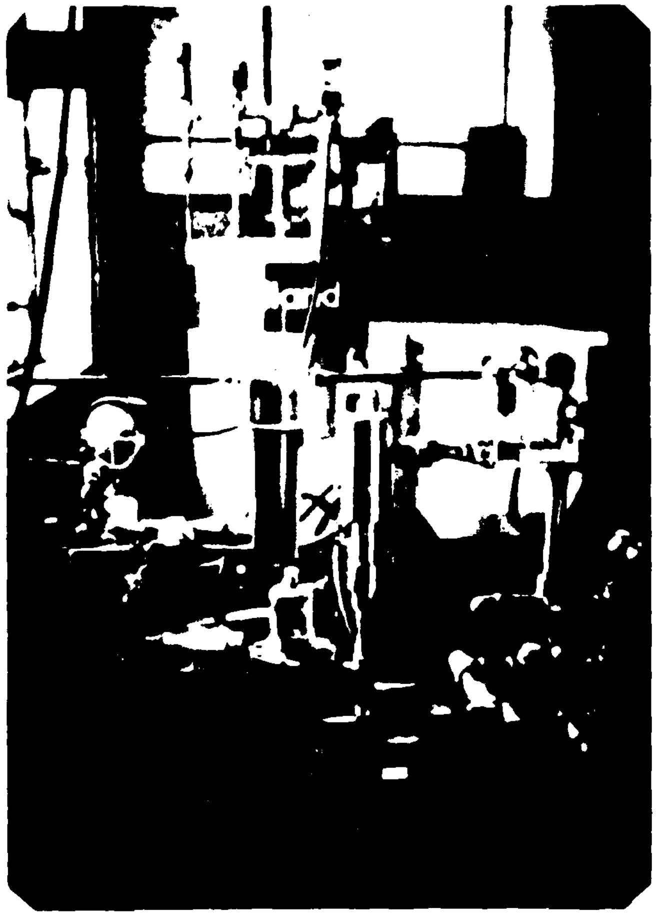


Photo B - Back View

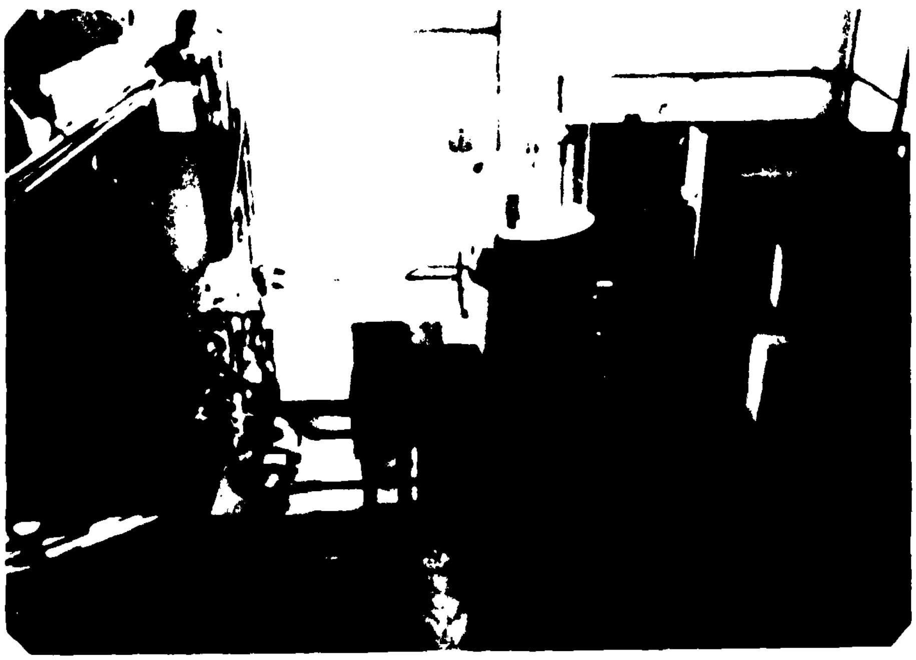
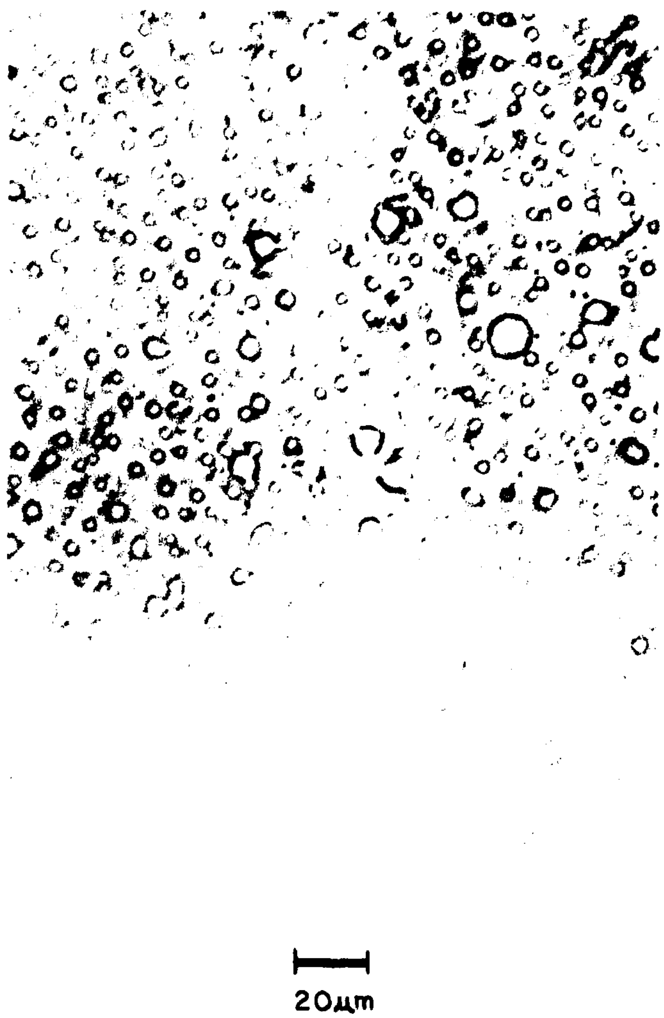


Photo C - Side View

Photographs of Folland ST 4.150 Emulsifier Installed
At U.S.C.G. Academy

FIGURE 3-8



500X Photomicrograph of 6% Water-in-Oil Emulsion Sample
Collected January 27, 1982 at the U.S.C.G. Academy

TABLE 3-1

SUMMARY OF WATER-IN-OIL DROPLET SIZE DISTRIBUTIONS DURING LONG TERM EMULSIFIED OIL TESTS

Water Droplet Size, mm	January 27, 1982 Water-In-Oil Emulsion		March 29, 1982 Water-In-Oil Emulsion	
	% of Total No. of Water Droplets of Size	% of Total No. of Water Droplets ≤ Size	% of Total No. of Water Droplets of Size	% of Total No. of Water Droplets ≤ Size
1	17.2	17.2	19.6	19.6
2	31.4	48.6	36.6	56.2
3	32.6	81.2	31.7	87.9
4	9.2	90.4	10.7	98.6
5	2.5	92.9	1.1	99.7
6	2.9	95.8	0.3	100.0
7	1.2	97.1		
8	1.7	98.8		
9	0.8	99.6		
10	0	99.6		
11	0	99.6		
12	0.4	100.0		

A third photomicrograph was taken of the 6% water in oil emulsion sample collected during the post long term emulsified oil tests. This photomicrograph is presented as Figure 3-9 and the results of the particle size count are included in Table 3-1.

3.6 Operating Procedures and Maintenance

Upon completion of the Folland Emulsion System installation, the initial start-up procedure for the Folland Emulsion System includes a check-out of the system's controls, and also serves to familiarize the operator with the systems operation. The edited initial start-up procedure from the Folland Manual is presented below. This procedure is most helpful in understanding the emulsion system's operation. Reference should be made to Figures 3-1 and 3-6 plus Drawings 0212-3001 and 0212-4001 in Appendix D for clarification.

Initial Start-Up

1) Before switching on power to the unit,
   - remove the water pump motor fuse (see Dwg. 0212-3001 in Appendix D)
   - remove the booster pump motor fuse
   - place temporary jumpers in the control panel to by-pass the following limit switches to allow the cycling valve to open and fill the receiver with fuel oil:
     a) low level in receiver limit switch
     b) low water level in the water supply tank limit switch

2) Slowly open oil supply valve (VLV-1 in Figure 3-6) and then oil return valve (VLV-2) observing that the fuel oil system pressure in the supply line does not fall below normal operating limits.

3) Open compressed air manual inlet valve to the automatic cycling valve on the main unit only. **DO NOT SUPPLY COMPRESSED AIR TO THE RECEIVER AT THIS TIME.**

4) Ensure that the valve (VLV-4 in Figure 3-1) in the oil line

FIGURE 3-9

500x Photomicrograph 6% Water-In-Oil Emulsion
March 29, 1982

to the Barodynamic Resonator and the emulsified oil line and the valve (VLV-5) in the emulsified oil line from the Barodynamic Resonator to the receiver are closed.

5) Put power on to the unit. Push start button and the cycling valve will open and a panel-mounted light will be illuminated.

6) Open fully VLV-4. Then, carefully and slowly, partially open VLV-5 while observing that the main fuel system pressure to the boiler does not drop below operating conditions. Opening this valve will allow oil to flow into the receiver, filling it. The cycling valve will automatically close when the upper level control in the receiver has been reached and the cycle valve indicator light will go out. Fully open VLV-5.

   While the receiver is filling, observe the pressure gauge on the top of the receiver to ensure that the pressure in the receiver does not exceed 20 psig.

   While the receiver is filling, adjust the oil pressure regulator (Figure 3-1) to give 120 to 150 psig on the pressure gauge on the Barodynamic Resonator. This pressure is determined by the size of the main nozzle in the Barodynamic Resonator and the capacity requirements of the system.

7) Disconnect power from the unit and replace the booster pump fuse. At the same time, remove the temporary jumper across low receiver level limit switch terminals. **DO NOT INSTALL WATER PUMP FUSE AT THIS TIME.**

8) Switch power on to the unit, and using the start and stop buttons, "JOG" the booster pump, observing that the motor and pump are turning in the right direction. Reverse direction if necessary. An arrow on the motor indicates the correct direction of rotation.

9) Start unit and operate it (without water pump operation) and adjust the booster pump output pressure to the required system pressure, using the emulsion pressure regulator (Figure 3-1). NOTE: this pressure may have to be readjusted after

the final receiver pressure adjustments.

10) Open the manual drain cock on the receiver vent pipe, in order to observe the vent flow while adjusting the receiver pressure.

11) Open the manual compressed air supply valve, supplying compressed air to the receiver and adjust the receiver pressure using the air pressure regulator (10) and the relief valve (see Drawing 0212-4001 in Appendix D).

12) Close the drain cock on the receiver vent pipe.

13) Open manual water inlet valve (35) and fill the water supply tank.

14) Disconnect power and remove the temporary jumper across low water supply tank level limit switch terminals.

15) Back out adjustment screw on the water pressure regulator

16) Put power back on to the unit and push the green "Start" button on the front operating panel, and hold in until all red indicator lights are out, and the "System Started" light comes on. Slowly open emulsion out valve (VLV-3, Figure 3-1) to its fully opened position. Slowly close emulsion system by-pass valve (VLV-6) and observe system for proper receiver filling.

17) Adjust the water flow to the desired amount, observing the water flow meter (17) using the water pressure regulator Make this adjustment only when the cycling valve is open, indicated by the pilot light on the front panel.

18) It may be necessary to re-adjust the oil pressure, using the oil back pressure regulator (2). If so, be sure to make this adjustment only when the automatic cycling valve is open, indicated by the pilot light on the front panel.

Normal System Shut-Down/Start-Up

To shut-down, first, increase the boiler excess air slightly to prevent smoking, then slowly open the system by-pass valve,

VLV-6 on Figure 3-1. After valve VLV-6 is fully opened, close emulsion out valve, VLV-3. Adjust boiler excess air. Press the red "Stop" button and close the oil supply valve, VLV-1, and return valve VLV-2. This completely isolates the emulsion fuel system from the boiler's neat fuel oil system.

To restart the system while the emulsion is still at the proper atomization temperature, the above procedure is reversed. If the oil in the system has cooled, ensure that power had been switched on to the unit for about 30 minutes before attempting a restart. This will allow the receiver temperature to reach a pumping temperature of 130^{o}F. The amber "Oil Temperature" light on the receiver will go out when the correct temperature has been reached. The 130^{o}F oil temperature will most likely be below the temperature required for proper atomization and therefore, it will be necessary to recirculate the oil or emulsion through the boiler's fuel oil heater to bring it up to the proper temperature. If an extended shutdown of the system is anticipated, the unit should be shutdown and the water pump fuse removed. The unit should then be restarted and run through a few cycles to fill the receiver with straight fuel oil. When oil is recirculated, the water pump should be left off until the system is up to the atomizing temperature. The system should then be stopped, the fuse replaced and the system started and lined up to discharge to the boiler.

Normal Operation and Maintenance Procedures

During the course of normal operation, the emulsion system should maintain the pressure and water flow rate set during the initial start-up of the unit. The particular operating conditions for the Folland Emulsion System during the emulsified oil tests are included in Table 3-2. No emulsion system adjustments were made unless the conditions deviated from those in Table 3-2. The oil temperature out of the fuel oil heater was regulated to maintain the oil viscosity at the burner for proper atomization (250 to 300 SSU).

The emulsifier system requires maintenance on a regular basis.

TABLE 3-2

SPECIFIED OPERATING CONDITIONS OF THE
FOLLAND EMULSION FUEL SYSTEM, MODEL ST 4.150
DURING WATER-IN-OIL EMULSION TESTS

Parameter	Unit Making Emulsion	Unit Not Making Emulsion
Fuel Oil Line Press., psig	134	150
Water Line Press., psig	230	230
Cell Press., psig	130	20
Water Flow Rate, gpm	0.40	-0-
Emulsion Press., psig	142	138
Receiver Press., psig	19.5	19.5

The manufacturers recommeded periodic maintenance schedule follows.

Every 100 Hours

Water Pump - squirt 3 drops of SAE 30 oil into each of the plunger seal holes.

Every 500 Hours

Water Pump - replace crankcase oil with SAE 30 oil. Crankcase must be filled to the center of the oil gauge window found on the rear of the crankcase.

Every 1000 Hours

Clean water inlet strainer.
Clean compressed air filter bowls.

Every 8000 Hours

Replace water orifice and main nozzle in Barodynamic Resonator. Replace all seals on cycling valve assembly, i.e. oil valve seals, water valve seals and actuator seals.

Replace diaphrams and seats in all pressure regulators and relief valves.

Replace belts (on belt driven water pumps).

Every 16000 Hours

Replace all ball valve seals.

Replace all actuator seals.

Replace water hoses.

Replace oil pump seals.

3.7 Acquisition and Operating Costs

3.7.1 Acquisition Cost

The purchase price of the complete Folland Fuel Emulsion System, Model ST 4.150, was $12,650 F.O.B. U.S.C.G. Academy, New London, Connecticut. The unit was ordered on November 11, 1980 and delivered to the test site on January 28, 1981.

The above price was for a basic non-automated system. One basic design change was made at no additional cost to the program. This change involved replacement of the backflow preventer in the water system with the tank and float valve configuration to provide a positive air break between the water and oil system. The additional cost for this modification would be approximately $450.00.

3.7.2 Operating Cost

The daily cost to operate the Folland Emulsion System, Model ST 4.150, has been calculated based on electrical power and water consumptions. The electrical services considered were the one (1) horsepower fuel oil booster pump motor, the 3/4 horsepower water pump motor, the air compressor motor and the emulsifier system's controls. The electrical heater in the receiver was not included because it is normally off during system operation. It's activated only when the receiver oil is being warmed after a shutdown. The system's electrical consumption was calculated from the measured voltages and amperages and motor manufacturer's power factors. The air compressor electrical consumption was based on the air useage, equal to the average daily volume of emulsified fuel oil burned during the long term emulsified oil test. The water useage was based on 6% of the average daily fuel oil useage.

The daily operating cost breakdown for the emulsion system is summarized in Table 3-3. These costs are based on the January 1982 utility rates for the U.S.C.G. Academy. The utility related operating costs amount to $3.27 per day to operate the emulsifier.

There are also costs associated with replacement parts for recommended maintenance. The daily costs attributable to replacement parts and lubrication following the Folland recommended schedule are included in Table 3-4 and amount to $1.77 per day. The resulting daily operating cost, utility plus maintenance, is $5.04 per day.

TABLE 3-3

FOLLAND ST 4.150 FUEL EMULSION SYSTEM
CONSUMPTION RATES AND DAILY UTILITY COSTS

Consumer	Amount Consumed Per Day	$ Per Day**
Power for 1 HP FO Booster Pump Motor	31.35 KW	$ 2.04
Power for 3/4 HP Water Pump Motor	14.41 KW	0.94
Power for Emulsor Controls	2.76 KW	0.18
Compressed Air for Emulsor*	296 ft^3 @ 20 psig	0.02
Water for Emulsor*	17.8 cu. ft.	0.09
TOTAL		$ 3.27

* Based on average of 2,215 gpd oil consumed during long term emulsified oil tests.

** Based on January 1982 utility cost of $0.065/KW-HR and $0.526/100 ft^3 water.

TABLE 3-4

DAILY OPERATING COSTS
FOR LUBRICANTS AND REPLACEMENT PARTS

Item	Recommended Replacement Schedule, Hrs	Cost Per Item, $	Cost Per* Day, $
12 Oz. Water Pump Crankcase Oil	500	$ 2.80	$ 0.13
Oil Pressure Control Valve Parts	8,000	74.00	0.22
Cycling Valve Parts	8,000	220.10	0.66
Receiver Parts	8,000	12.70	0.04
Receiver Parts	16,000	29.80	0.05
Barodynamic Resonator Parts	8,000	103.76	0.31
Water Pump Parts	8,000	22.50	0.07
Booster Pump	16,000	42.00	0.06
Water Hoses	16,000	156.00	0.23
TOTAL			$ 1.77

* Price of October 1980

3.8 Emulsion System Performance History

Overall, the emulsion system operation was relatively trouble free. There were only minor electrical and mechanical problems which occurred during the test program. These problems are discussed below.

* Emulsion fuel system shut down after the first hour of operation after start-up due to a blown fuse (F1). Inspection of the wiring diagram and the unit's wiring revealed that fuse F1 was in series with fuses F2 and F3. After consultation with Folland Corporation, the wiring was changed so that fuses F1, F2 and F3 are in parallel (see Drawing No. 0212-3001 in Appendix D).

* It was noted that during the emulsified oil optimization tests that the wires in the control cabinet were overheated and discolored. These wires connect the fuses and neutral side to the power leads and were 16 AWG. The problem was due to the use of undersized wire for the 24 amps drawn by the unit and the 16 AWG wires were replaced with 12 AWG wires. Folland normally manufactures their emulsifiers for 440V AC three-phase current, in which case, the 16 AWG wire would have been sufficient for the lower amperage. The emulsifier at the Academy is powered by 115V AC single-phase current due to the available service.

* On August 26, 1981, the emulsifier shut down on low receiver level and the recycling valve would not open. The problem was found to be the low level control switch stuck in the open position. The low level switch was cleaned and operated freely.

* The bearings on the Folland Emulsifier fuel oil pump motor failed on December 1, 1981. The manufacturer supplied a replacement motor.

* On January 20, 1982, the Folland Emulsifier shut down due to a low receiver level. The problem was found to be a stuck low level switch which was cleaned and freed. There had also been a problem maintaining the proper water pressure and flow. The

flexible water line from the air-operated valve to the Barodynamic Resonator was found to be partially plugged. The entire water system was drained and flushed and the water regulating valve was inspected and the valve ground in. A leaky seal in the air-operated control valve was replaced and the fuel oil booster pump disassembled for seal replacement. Upon inspection, the fuel pumps main bearings were found to be badly worn and in need of replacement. The manufacturer supplied new bearings for the fuel oil booster pump.

* On February 9, 1982, U.S.C.G. Acadmey personnel reported that the water regulating valve was again sticking and that they were not able to maintain the proper water pressure and thus, the correct water flow rate. Inspection of the valve internals showed rust on the guide seat which was believed to have caused the problem. The presence of rusting in the system was unexpected because the system remained full of water since installation. However, the return from the pump discharge to the tank was above the water level and it is possible that air enrichment occurred, resulting in the rusting. The piping was therefore modified so that the regulating valve would discharge to the pump suction rather than the water tank. The regulating valve's rusted parts were replaced and the system functioned properly.

* On February 24, 1982, U.S.C.G. Academy personnel reported that the emulsifier fuel oil regulating valve was leaking through the bleeder hole which indicated a bad diaphram. Folland supplied a new diaphram.

The above problems are not believed to be indicative of any chronic machinery troubles which could require upgrading. It is recommended that the level switches be inspected and cleaned quarterly.

3.9 Recommended Modifications to Fuel Oil and Emulsion Systems At The U.S.C.G. Academy

First, it is recommended that the Quick Closing Emergency

Shut-Off Valve be relocated downstream of the emulsifier piping connections in the fuel oil system. Referring to Figure 3-6, the Quick Closing Emergency Shut-Off Valve is located upstream of the emulsifier piping connections in the fuel oil system. The Quick Closing Emergency Shut-Off Valve is fitted with a fusible link which is designed to melt in a fire and thereby allow the valve to close by spring-tension and shut-off the oil supply to the burners. In its present configuration with the emulsifier operating, if the Quick Closing Emergency Shut-Off Valve closes, the emulsifier will shut down due to a low fuel oil pressure. This action was believed to stop the emulsified oil flow, however, it has been observed that even though the fuel oil pump has stopped, the 20 psi pressure of the emulsified oil in the receiver is sufficient to maintain some fuel flow to the burners. This situation represents a potentially hazardous condition because all emulsified fuel to the boiler is not immediately stopped.

It is also recommended that the emulsifier discharge ball valve, VLV-3 in Figure 3-6, be fitted with an air operated actuator and a three-way solenoid valve which would provide a positive fuel oil shut-off to the boiler when the emulsifier shuts down. This recommendation is made based on the following occurance during the long term emulsified oil test.

During the change-over of the fuel oil duplex strainer, a momentary low fuel line pressure caused the emulsifier shut down on the low oil pressure safety trip. Although the emulsifier booster pump had stopped, the pressure in the receiver maintained sufficient oil flow to the burners so that the fires remained lit. There was not, however, enough flow of oil to maintain the boiler steam pressure. As the steam pressure fell off, the automatic combustion control system increased the fuel oil regulating valve opening to compensate. Noticing that the emulsifier had shut down, the operator restarted it. Consequently, this caused an excess amount of fuel to be pumped into the boiler with some of this fuel passing into the furnace without being burned at the burners. When this fuel did ignite, a flare-back occurred which, fortunately, caused no perceiv-

able damage to the boiler.

Although the flare-back is directly attributable to an improper operating procedure in that the boiler should have been shut down and relit, the addition of the air operated actuator would have prevented the flare-back. The actuator, three-way solenoid valve and bracket cost approximately $320. The three-way solenoid valve would be connected electrically to the fuel booster pump power supply and would be piped to maintain air pressure on the ball valve actuator when the booster pump is operating. In the event of an emulsifier shut down, the power supply to the booster pump is interrupted which would cause the three-way solenoid valve to close the air supply and vent the actuator. The actuator spring-tension would then close the emulsifier discharge valve (VLV-3 in Figure 3-6) and stop the emulsified fuel flow to the boiler.

3.10 Spare Parts

Table 3.5 contains the manufacturer's recommended spare parts inventory and correspond to the replacement parts for the 8,000 hour and 16,000 hour scheduled maintenance. These parts appear reasonable, based on the operating experience with the unit at the U.S.C.G. Academy.

TABLE 3-5

RECOMMENDED SPARE PARTS INVENTORY FOR FOLLAND ST 4.150 EMULSION FUEL SYSTEM

Description of Item On Which Part Is Used	Qty of Part Req'd	Description and Number of Part
Oil pressure control Fisher 95H- 1"	1	Orifice 416 SST (metal seat) P/N IE3980 46172
	1	Valve plug 416SST P/N 1E3981 46172
	2	Diaphram 302SST P/N 1E3992 36012
	1	Gasket P/N 1E3993 04022
	2	Gasket P/N 1P7880 04022
	1	O ring P/N 1P7859 06242
Cycling valve assembly-Actuator	1	Repair kit for solenoid valve block assembly
	1	Solenoid operator
	1	Center gear retaining washer
	6	Piston guide rod bearings
	1	Circlip for center gear
	6	O rings for guide rods
	1	O ring for upper center gear
	1	O ring for lower center gear
	2	End cap O rings
	2	Piston O rings
Cycling valve assembly-Oil valve	2	Belleville washers
	1	Stem seal

TABLE 3-5
CONTINUED

Description of Item On Which Part Is Used	Qty of Part Req'd	Description and Number of Part
Cycling valve assembly-Oil valve (Continued)	1	Thrust bearing
	2	Seat
	2	Body seal
Cycling valve assembly-Water valve	2	Belleville washers
	1	Stem seal
	1	Thrust bearing
	2	Seat
	2	Body seal
Receiver-Relief valve Fisher 289H	1	Gasket P/N 1F8268 0402
	1	O ring P/N 1F8266 0699
	2	O ring P/N 1D6875 0699
	1	Diaphragm P/N 1E6066 0205
Regulator, air pressure	1	Complete assembly. Fisher type 67- 0-35 psi
Barodynamic Resonator	1	Main nozzle
	1	Water orifice disc
	1	Water orifice core
	1	Resonator drum
	1	Set O ring seals
Water pump	3	Kit - seal 877530
	1	Drive belt
Booster pump	1	Replacement mechanical seal
Miscellaneous	1	Set of water hoses

4.0 PROGRAM RESULTS

Introduction

This section presents the results of all measurements, both qualitative and quantitative, made relative to the test boiler at the U.S.C.G. Academy. These measurements are categorized as follows:

* Boiler efficiency
* Boiler particulate and oxide of nitrogen emissions
* Boiler tube material
* Boiler tube surface deposits
* Boiler inspections

4.1 Efficiency Test Results

The boiler efficiency was determined and calculated in accordance with the Abbreviated Efficiency Test Method of PTC 4.1 of The American Society of Mechanical Engineers Power Test Codes for Steam Generating Units, using Code specified instrumentation. The Abbreviated Efficiency Test Method calculates efficiency from heat output/input and the heat loss. The method considers only the major losses, and only the chemical heat in the fuel as input, it ignores the minor losses and heat credits. These minor heat losses (moisture in air, heat in atomizing steam, sensible heat in fuel, primary air fan power and heat supplied by moisture in entering air) have a negligible impact upon the calculated efficiencies. Their impact will be further minimized because these efficiencies are compared with other test series with the minor heat losses and credits being similar for each test series. Section 2.5.1 contains a complete description of the efficiency testing.

This section presents only those efficiencies as measured by the heat input-output method. Much more confidence is placed in the efficiencies as measured by the heat input-output method as compared to the heat loss method because all the parameters used in the heat input-output method were measured using calibrated instruments. In the heat loss method, several parameters (combustibles

in fly ash, radiation and unmeasured losses) are either assumed or from curves which may not be accurate for the test boiler. The completed ASME Test Forms for all efficiency tests are included in Appendix E.

The efficiency testing program was designed to cover the boiler operating range of 25% to 100% of the rated capacity of 28,500 LBS/HR. Thus, eight (8) load levels were run for each test series. The efficiency data for each test series were fit to a parabola of the form:

$$y = a + bx + cx^2$$

using the least square method. Graphs depicting the test data points and the fitted curves for all tests are presented in Appendix F.

The desired load levels were obtained by adjusting the boiler's firing rate to the desired load level. Excess steam generated was manually dumped to the atomosphere through a line from the steam header to silencers above the boiler room roof. The test boiler was operated at a constant firing rate with the steam dump valve modulated to maintain the required steam pressure. Summaries of the combustion and operational parameters during each test are included as Appendix G.

The efficiency testing was performed during each of the test series which were run to determine the following:

* The improvement in efficiency due to boiler cleaning and tuning
* The degradation in efficiency after long term continuous operation on neat (unconditioned) oil
* The difference in efficiency when firing emulsified oil as compared to neat oil
* The degradation in efficiency after long term continuous operation on emulsified oil
* Any changes in efficiency of the cleaned and tuned boiler on neat oil during the entire test period

TABLE 4-1

SCHEDULE OF EFFICIENCY TESTS PERFORMED ON BOILER NO. 3 AT U.S.C.G. ACADEMY

Test Dates	Description of Test Series
8/12-15/1980	Preliminary tests on untuned, dirty boiler firing neat oil
9/9-18/1980 and 10/7-8/1980	Pre Long Term tests on tuned, cleaned boiler firing neat oil
5/4-13/1981	Post Long Term tests after eight and one-half (8½) months firing neat oil
6/8-12/1981	Interim Baseline tests on tuned, cleaned boiler firing neat oil
6/22-30/1981	Pre Long Term tests on tuned, cleaned boiler firing emulsified oil
3/22-30/1982	Post Long Term tests after nine and two-thirds (9-2/3) months firing emulsified oil
4/12-15/1982	Final Baseline tests on tuned, cleaned boiler firing neat oil

Testing was broken down into individual test series to allow for comparison in the determination of the above. Table 4-1 is a summary of the test series with the test dates.

4.1.1 Base Line Tests

The interim base line and final base line neat oil tests were conducted immediately after boiler cleaning and tuning to determine if the boiler had been properly cleaned and tuned and if there had been a shift in boiler performance which would bias any test results. The completed ASME Test Forms for the tests are included in Appendix E. The efficiency test results for the Pre Long Term, Interim Base Line and Final Base Line Neat oil tests are plotted on Figure F-2, F-4 and F-7 in Appendix F, along with the curves of best fit of each data set. These results were compared with the Pre Long Term neat oil tests and the results presented graphically in Figure 4-1 and tabulated in Table 4-2.

TABLE 4-2

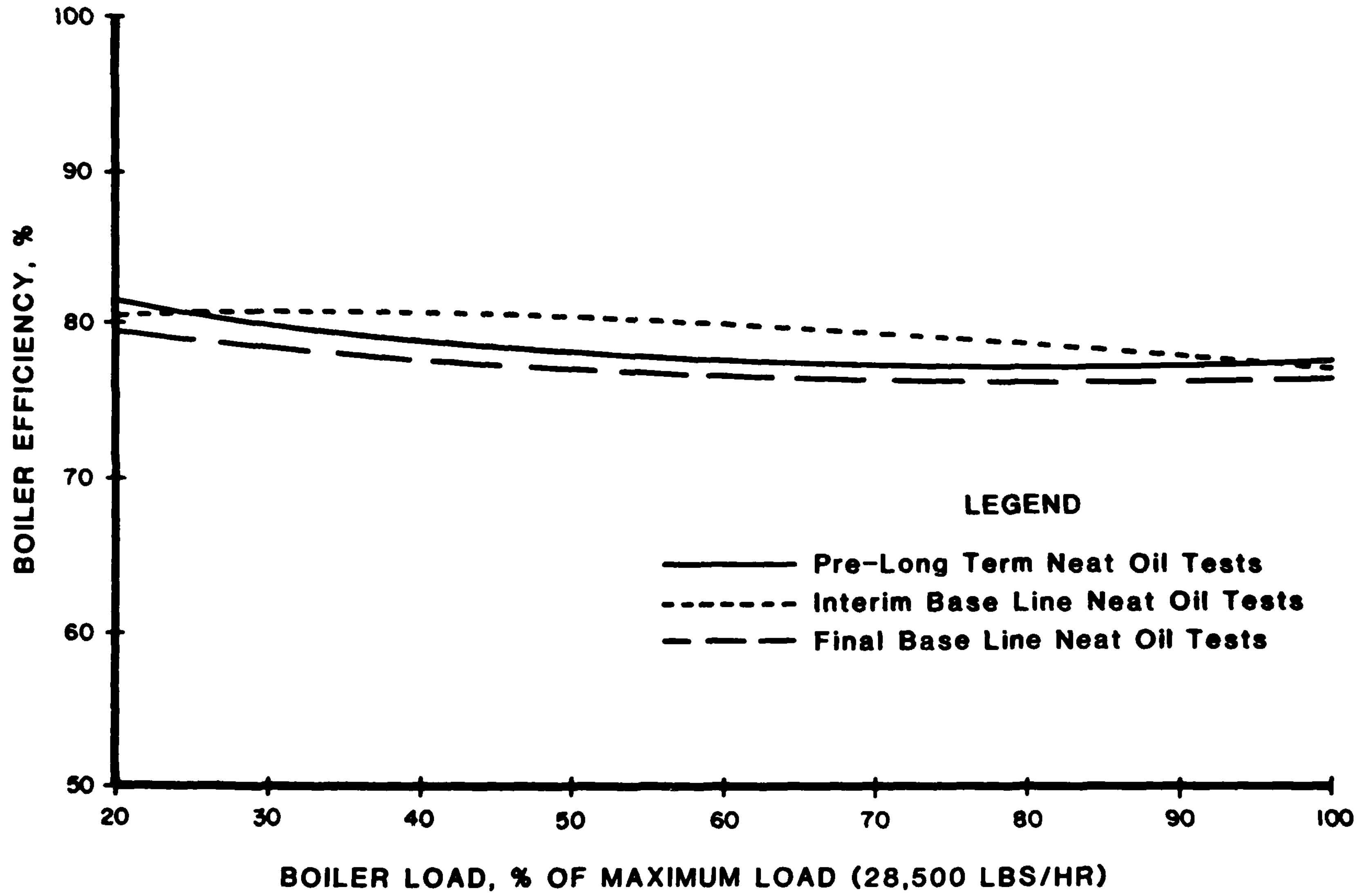
PRE LONG TERM, INTERIM BASELINE AND FINAL BASELINE NEAT OIL EFFICIENCY TEST RESULTS

	Heat Output/Input Efficiency From Curve Fit of Test Data, %			Arithmetic Avg. of Pre Long Term, Interim Baseline & Final Baseline Results, %
Boiler Load,%	**Pre Long Term**	**Interim Baseline**	**Final Baseline**	**Averaged Baseline**
30	80.1	80.8	78.6	79.8
50	78.2	80.5	77.2	78.6
70	77.3	79.6	76.4	77.8
90	77.3	78.1	76.3	77.2

The variability in efficiencies observed in these test results is believed to be the result of a combination of the allowable instrument errors and operator differences, and no significant shift in boiler performance is suspected during the test period. The mathematical average of the three curves is used as the basis for

Figure 4-1

Comparison of Pre-Long Term, Interim Base Line and Final Base Line Neat Oil Efficiency Tests, Curve Fits of Heat Output/Input Data



the test data comparisons for the other tests to follow.

4.1.2 Preliminary versus Averaged Baseline Neat Oil Test

The purpose of the Preliminary Neat Oil Efficiency Tests was to establish the operating efficiency of the boiler over its operating range before the fireside and waterside cleaning and extensive tuning. The Preliminary Neat Oil efficiency test results are compiled on the ASME Test Forms in Appendix E. The efficiency test results for each load level is plotted along with the curve of best fit in Appendix F (see Figure F-1). These results are compared with the Averaged Baseline Neat Oil Tests in Figure 4-2 and summarized on Table 4-3. Noting Figure 4-2, boiler cleaning and tuning improved efficiency over the entire operating range with the greatest improvements in the lower 20% - 40% and higher 80% - 100% load ranges. Table 4-3 shows the largest regain in efficiency to be 2.9% at 30% load. The smallest regain in efficiency was 0.6% at 70% load. These results are consistent with the boiler being operated at high excess air levels at low load levels during the preliminary tests, causing the reduced efficiency at the lower power levels. The dirty tube surfaces are believed to have been the cause of the lower efficiency over the entire range with the highest losses occurring at the higher load levels.

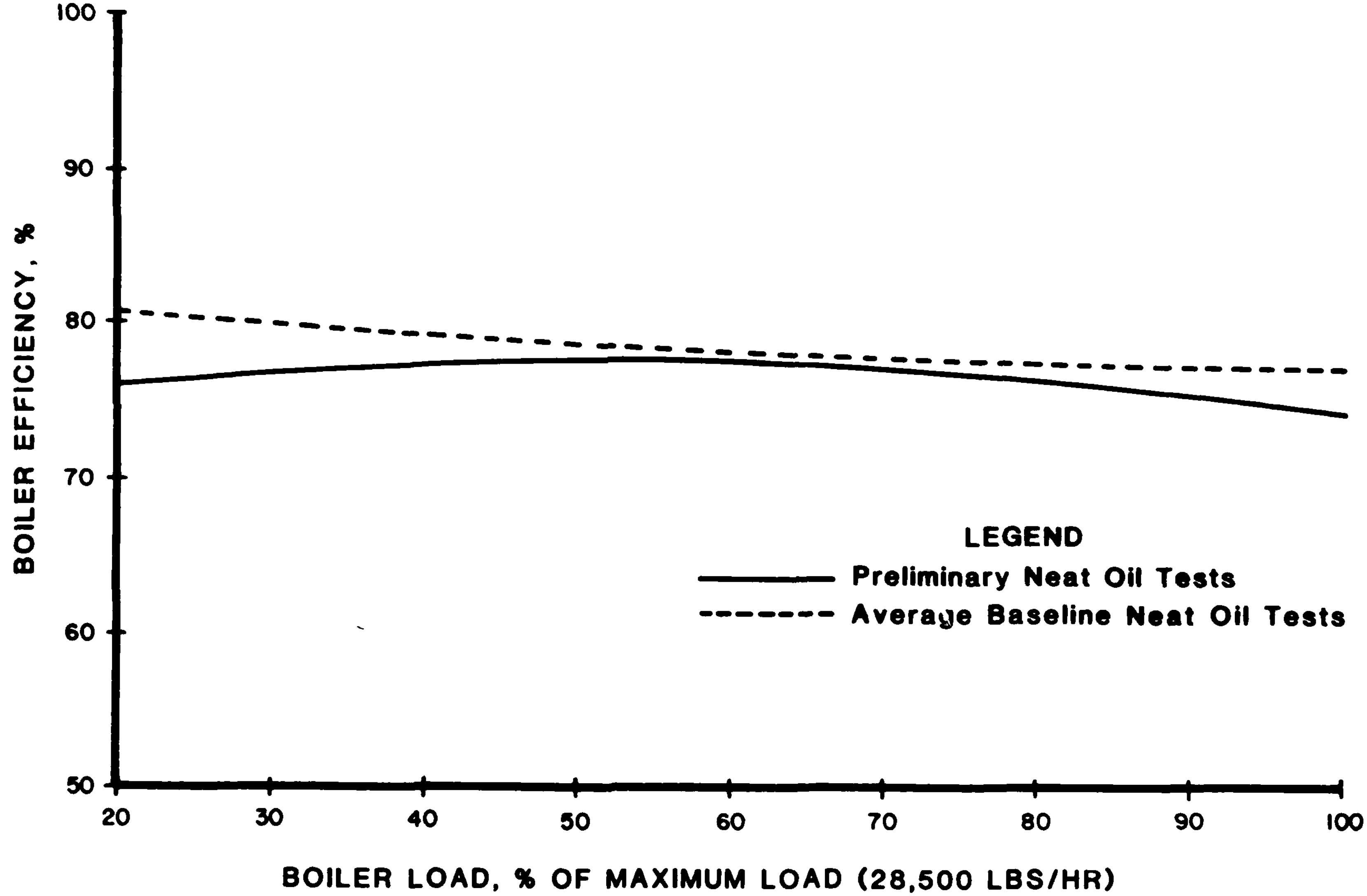
TABLE 4-3

EFFICIENCY TEST RESULTS, COMPARISON OF PRELIMINARY AND AVERAGED BASELINE NEAT OIL TESTS

	Heat Output/Input Efficiency From Curve Fit of Test Data,%		
Boiler Load, %	Preliminary	Averaged Baseline	Averaged Baseline Efficiency Minus Preliminary Efficiency, %
30	76.9	79.8	2.9
50	77.7	78.6	0.9
70	77.2	77.8	0.6
90	75.5	77.2	1.7

Figure 4-2

Comparison of Preliminary and Averaged Base Line Neat Oil Efficiency Tests, Curve Fits of Heat Output/Input Data



4.1.3 Post Long Term versus Averaged Baseline Neat Oil Tests

The purpose of the Post Long Term Neat Oil Efficiency Tests was to determine the operating efficiency of the boiler after prolonged operation. This data was compared to the Averaged Baseline Neat Oil Efficiency Test data to determine the extent of degradation due to fouling of the boiler tube surfaces during a period of typical operation on neat oil. This data is also to be compared with the degradation during the long term emulsified oil tests to determine if there is any difference in the rate of tube fouling when firing an emulsified oil rather than a neat oil. The Post Long Term Neat Oil Efficiency test results are tabulated on the ASME Test Forms in Appendix E. Appendix F (Figure F-3) illustrates the test results and the curve of best fit of the test data. Table 4-4 and Figure 4-3 present comparisons of the statistical test results of the Post Long Term and the Averaged Baseline Neat Oil Tests. The results indicate a degradation or loss in the boiler efficiency for the entire load range with the highest loss in efficiency occurring at the high loads (1.8% @ 90% load). The result was as expected in that the soot accumulation on the boiler fireside caused reduced heat transfer over the entire load range with the *maximum loss occurring* at high loads when gas flow is maximum and therefore the time for heat transfer is minimum.

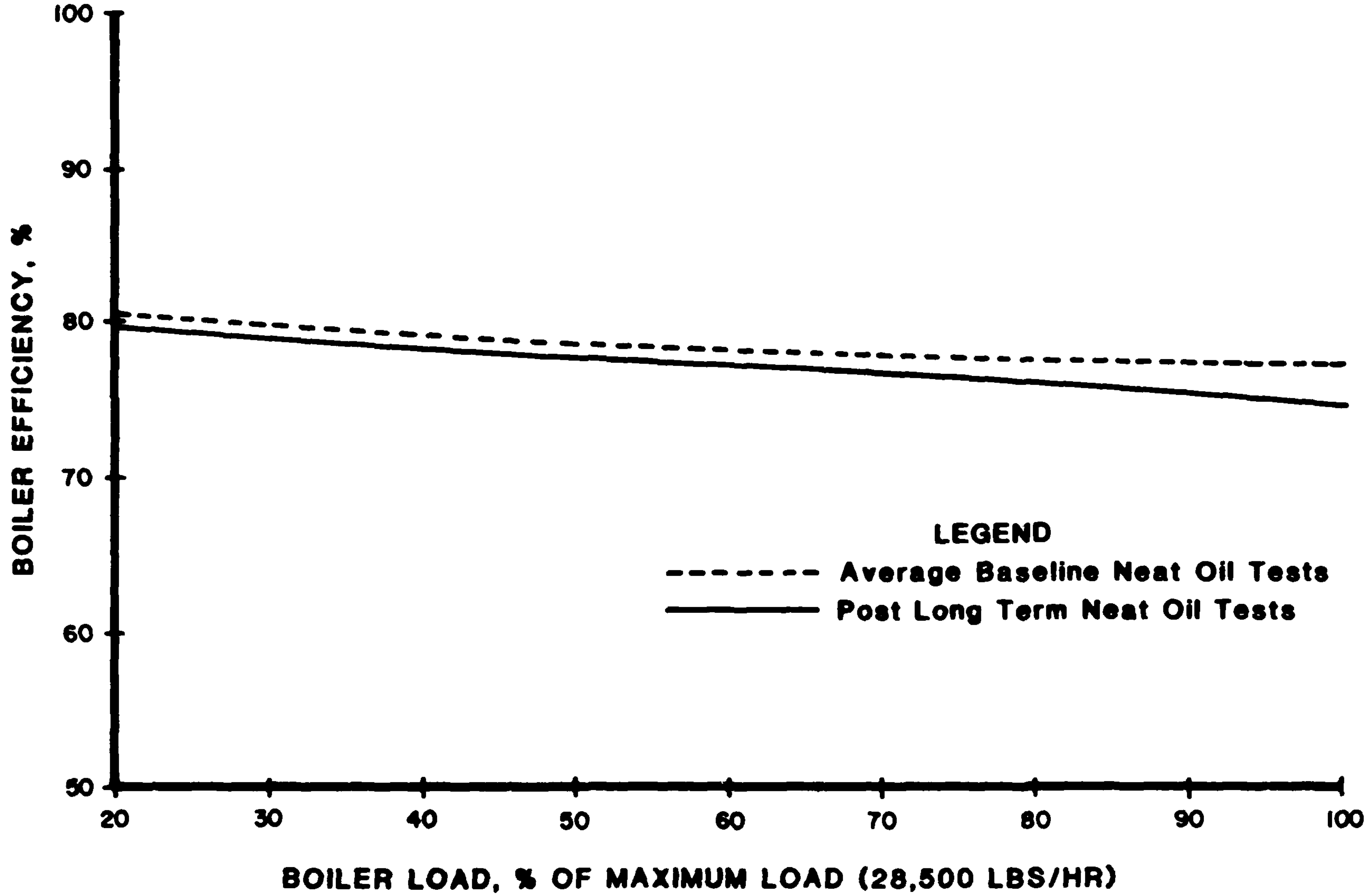
TABLE 4-4

EFFICIENCY TEST RESULTS, COMPARISON OF POST LONG TERM AND AVERAGED BASELINE NEAT OIL TESTS

	Heat Output/Input Efficiency From Curve Fit of Test Data,%		
Boiler Load,%	**Post Long Term**	**Averaged Baseline**	**Averaged Baseline Efficiency Minus Post Long Term Efficiency, %**
30	79.1	79.8	0.7
50	77.8	78.6	0.8
70	76.6	77.8	1.2
90	75.4	77.2	1.8

Figure 4-3

Comparison of Averaged Base Line and Post Long Term Neat Oil Efficiency Tests, Curve Fits of Heat Output/Input Data



4.1.4 Pre Long Term Emulsified Oil versus Averaged Baseline Neat Oil Tests

The purpose of the Pre Long Term Emulsified Oil Efficiency tests was to quantify the operating efficiency of the cleaned and tuned boiler firing emulsified oil. This data was compared to the Averaged Baseline Neat Oil Efficiency Test data to determine the extent of efficiency gains or penalties due to firing an emulsified oil. The Pre Long Term Emulsified Oil Efficiency Test results are tabulated on the ASME Test Forms in Appendix E. Figure F-5 in Appendix F graphically represents the test results plus the curve of best fit of the test data. Table 4-5 and Figure 4-4 present the comparisons of the statistical test results of the Pre Long Term Emulsified and the Averaged Baseline Neat Oil Tests. The results show that the boiler was more efficient on emulsified oil over the 47% to 91% boiler load range, however, the maximum gain in efficiency was small (0.7%). The shift from an efficiency loss with the emulsified oil for boiler load less than 47% to an efficiency gain for the 47-91% boiler load and back to an efficiency loss for boiler load greater than 91% is not consistent with what would be expected.

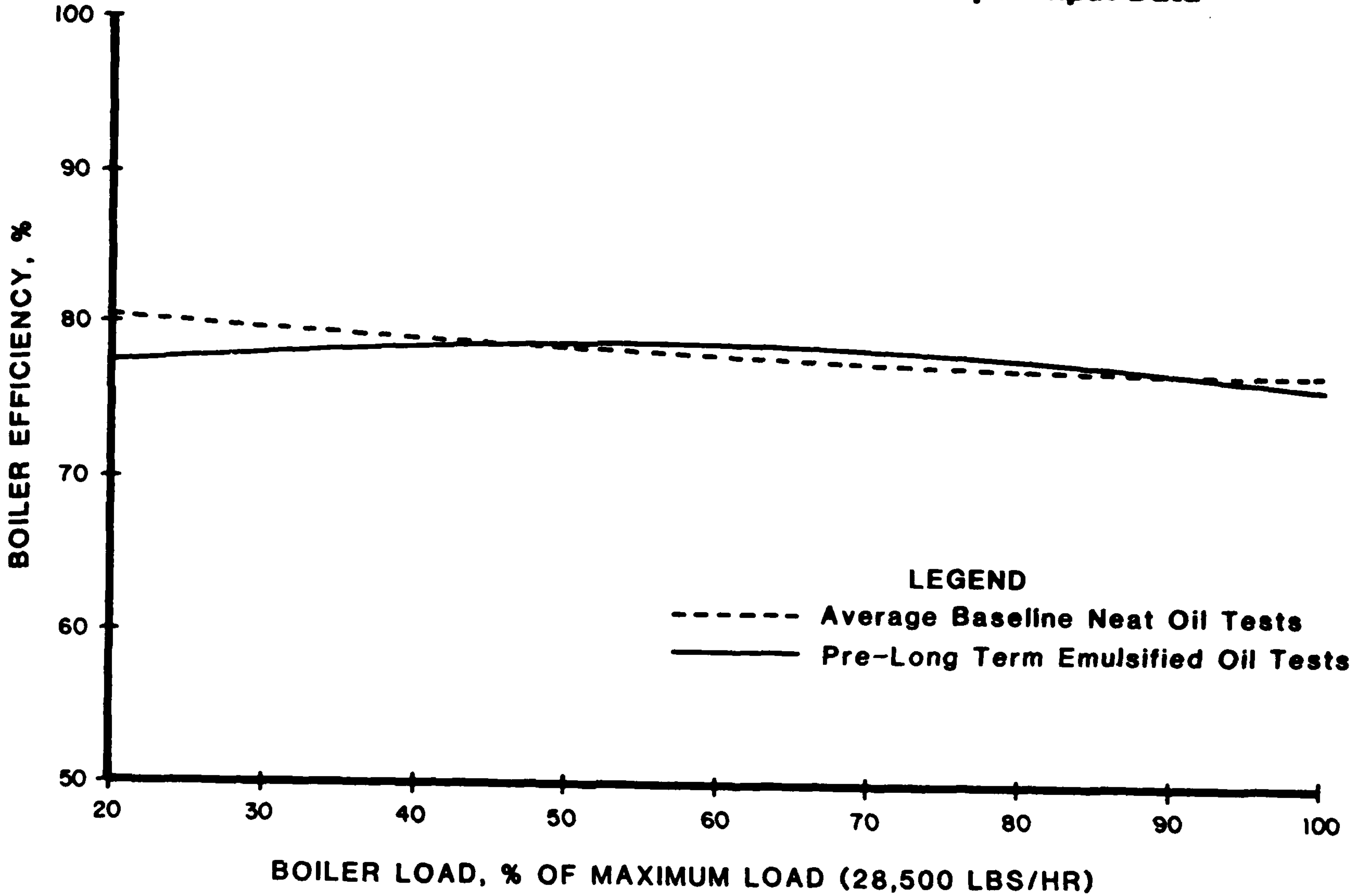
TABLE 4-5

EFFICIENCY TEST RESULTS, COMPARISON OF PRE LONG TERM EMULSIFIED AND AVERAGED BASELINE NEAT OIL TESTS

	Heat Output/Input Efficiency From Curve Fit of Test Data,%		
Boiler Load,%	Pre Long Term Emulsified	Averaged Baseline	Pre Long Term Emulsified Efficiency Minus Averaged Baseline Efficiency, %
30	78.2	79.8	- 1.6
50	78.9	78.6	0.3
70	78.5	77.8	0.7
90	77.2	77.2	0.0

Figure 4-4

Comparison of Averaged Base Line Neat Oil and Pre-Long Term Emulsified Oil Efficiency Tests, Curve Fits of Heat Output/Input Data



The reason for the unexpected results are believed to be operator differences. Further, comparison of the particulate emission test results (see Section 4.2.2) shows a considerable reduction in the particulate emissions during both high and low load tests. This reduction in particulate emissions while firing an emulsified oil indicates that it would have been possible to further trim the excess air during the emulsified oil tests. A more detailed discussion of the relationship between efficiency, emissions and excess air is presented in Section 4.5.1.

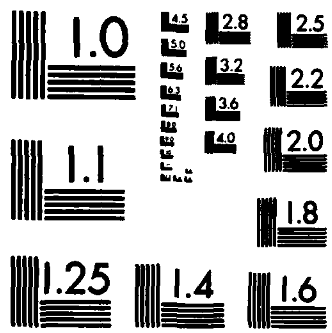
4.1.5 Pre versus Post Long Term Emulsified versus Post Long Term Neat Oil Tests

The purpose of the Post Long Term Emulsified Oil Efficiency Tests was to determine the operating efficiency of the boiler after firing emulsified oil for a prolonged period. This data was compared to the Pre Long Term Emulsified Oil Efficiency Test data to determine the extent of degradation due to fouling of the boiler tube surfaces during a period of typical operation on emulsified oil. The data was also compared to the Post Long Term Neat Oil Efficiency Test data to assess the differences in boiler efficiency degradation for the different oils. The Post Long Term Emulsified Oil Efficiency Test results are tabulated on ASME Test Forms in Appendix E. Appendix F (Figure F-6) illustrates the test results and shows the curve of best fit of the test data. Table 4-6 and Figure 4-5 present comparisons of the statistical test results of the Pre and Post Long Term Emulsified Oil Tests.

The results show the expected degradation in boiler efficiency for boiler loads greater than 44%. The improvement in efficiency for the lower load tests again, as in Section 4.1.4, indicates that excess air was not trimmed as much as possible during the Pre Long Term Emulsified Oil Efficiency Tests. Figure 4-6 presents the graphical comparison of the post long term neat and emulsified oil tests. The graph shows that the boiler efficiency was the same or higher at the end of the long term emulsified oil test, indicating a slightly cleaner boiler than at the conclusion of the long term neat oil test.

AD-A121 011 SHORESIDE BOILER DEMONSTRATION OF FUEL-WATER EMULSIONS 2/4
(U) SEAWORTHY ENGINE SYSTEMS INC ESSEX CT
R W CASS ET AL. AUG 82 USCG-D-04-82 DTCG23-80-C-20001

UNCLASSIFIED F/G 21/4 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Figure 4-5

Comparison of Pre and Post Long Term Emulsified Oil Efficiency Tests, Curve Fits of Heat Output/Input Data

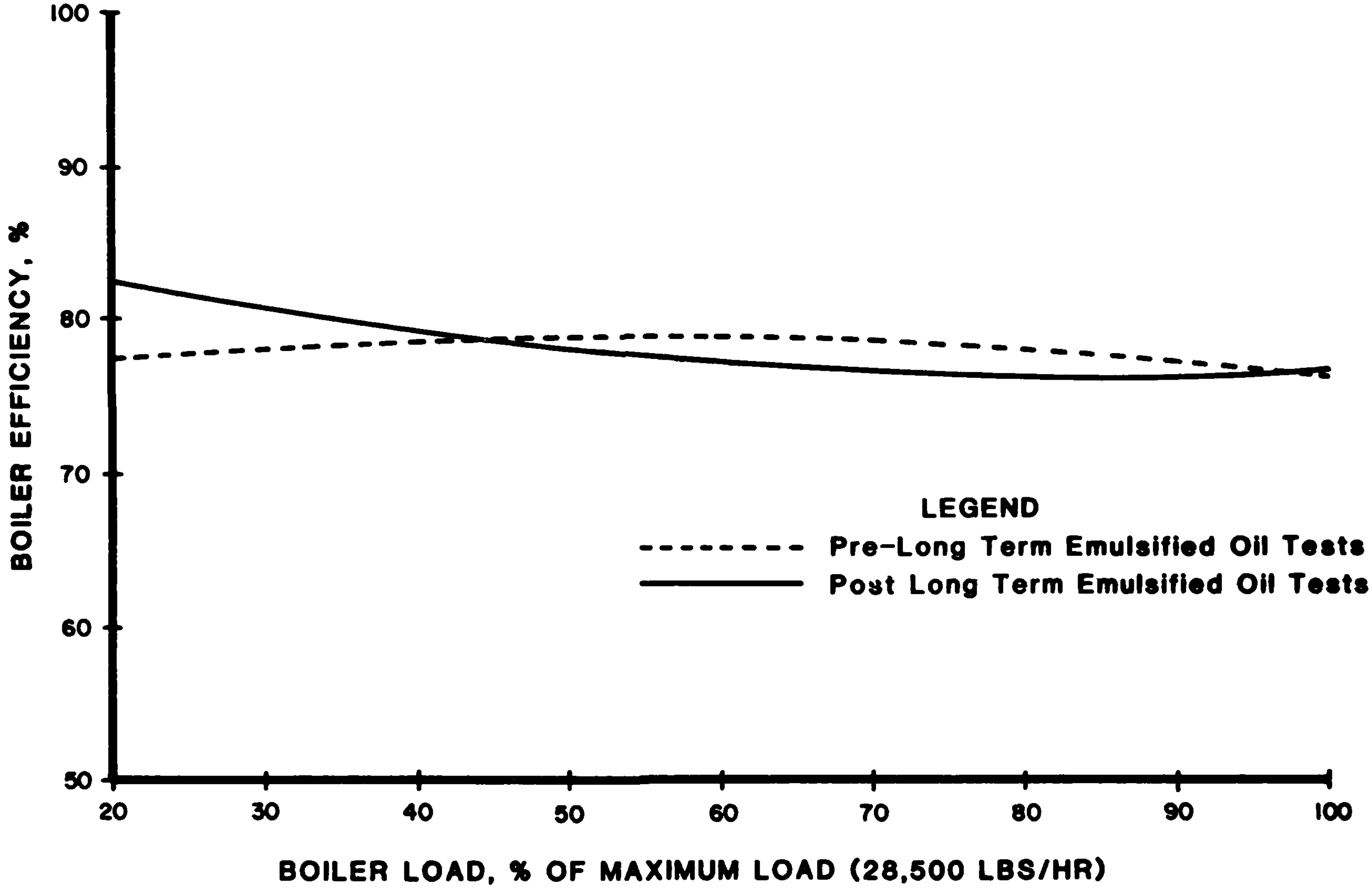


Figure 4-6

Comparison of Post Long Term Neat Oil and Post Long Term Emulsified Oil Efficiency Tests, Curve Fits of Heat Output/Input Data

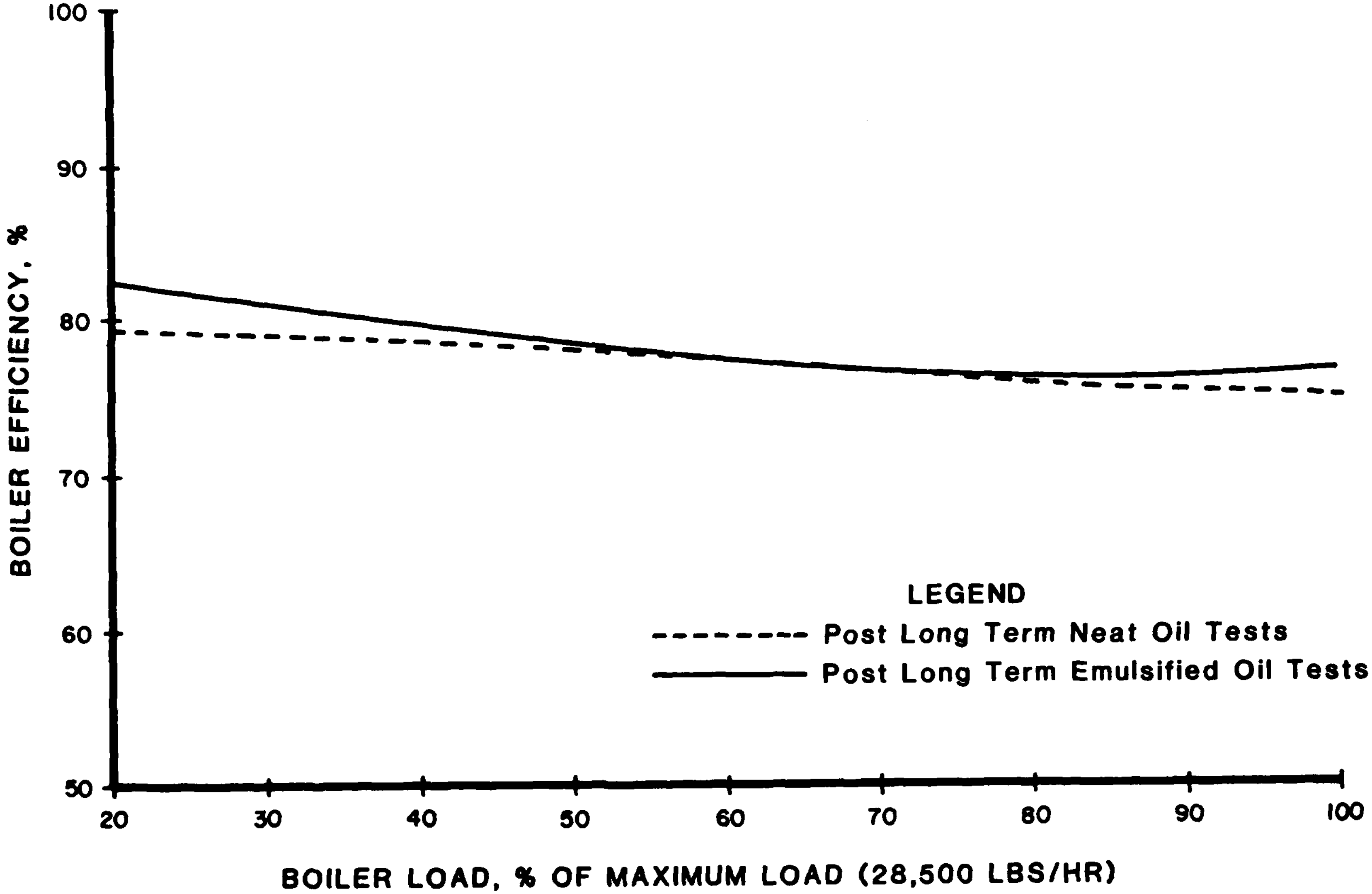


TABLE 4-6

EFFICIENCY TEST RESULTS, COMPARISON OF PRE AND POST LONG TERM EMULSIFIED OIL TESTS

Boiler Load,%	Heat Output/Input Efficiency From Curve Fit of Test Data,%: Pre Long Term Emulsified	Heat Output/Input Efficiency From Curve Fit of Test Data,%: Post Long Term Emulsified	Pre Long Term Emulsified Efficiency Minus Post Long Term Emulsified Efficiency
30	78.2	81.0	- 2.8
50	78.9	78.2	0.7
70	78.5	76.7	1.8
90	77.2	76.3	0.9

4.2 Emission Test Results

The boiler's particulate emissions were measured in accordance with EPA Reference Methods 1 through 5. The test boiler's flue gas was sampled with two (2) sampling trains simultaneously to reduce the time required for emission testing. The particulate concentration was determined by extracting a sample of the flue gas stream isokinetically and removing the particulate from the sample stream with a tared glass fiber filter. The particulate concentration was calculated from the gravimetric analysis of the filter and the volume of gas sampled. The oxide of nitrogen emissions were measured during each particulate test using a Monitor Labs Model 8430 NO_x Monitor. The analyzer first thermally converts all the NO_x to NO, then measures NO concentration by chemiluminesence. Section 2.6 contains the complete details of the particulate and oxide emission testing.

The boiler flue gas particulate and oxide of nitrogen emissions were measured at boiler high and low load levels during the pre and post long term neat oil and emulsified oil tests. The particulate and NO tests were repeated five (5) times at each boiler load level to provide sufficient data for statistical comparison.

4.2.1 Pre versus Post Long Term Neat Oil Tests

The results of the emission tests for the Pre and Post Long Term Neat Oil Tests are presented in Tables H-1, 2, 3 and 4 in Appendix H. Table 4-7 is a summary of the emission test results for the Pre and Post Long Term Neat Oil Tests. Table 4-7 also contains the fuel oil ash content expressed as pounds per million BTU's of fuel oil fired, the percentage by weight of nitrogen in the fuel and the percentage of flue gas excess air during each test series. Comparison of both high and low load particulate results (see Table 4-7) for the Pre and Post Long Term Neat Oil Test shows a considerable decrease in the particulate emissions during both the high and low load tests. This is believed to have been the result of operating with the Hagan Combustion Control System in the manual mode during the Post Long Term Neat Oil Tests. Unstable combustion occurred at times during the Pre Long Term Neat Oil Tests when the steam dump valve was opened or closed too quickly and the Hagan system compensated for the sudden pressure change. The fuel oil ash content was also lower for the Post Long Term Neat Oil Tests. However, the difference in particulate emissions cannot be totally explained by the higher fuel oil ash content during the Pre Long Term Test.

The results of the oxides of nitrogen tests indicate that the oxides of nitrogen emissions were nearly the same for Pre and Post Long Term Tests. The Post Long Term oxides of nitrogen emissions at low load were 11% lower than the Pre Long Term and at high load were 3% lower. The lower fuel oil nitrogen content (see Table 4-7) during the Post Long Term Tests is consistent with the lower emissions.

4.2.2 Pre Long Term Emulsified versus Pre Long Term Neat Oil Tests

The results of the emission tests for the Pre Long Term Emulsified and Neat Oil Tests are included in Appendix H as Tables H-1 and 2 and H-5 and 6. The result summaries are listed in Tables 4-7 and 4-8 which also contain the fuel oil ash content expressed as pounds per million BTU's of fuel oil fired, the percentage by

TABLE 4-7

SUMMARY OF PRE AND POST LONG TERM NEAT OIL TESTS, PARTICULATE AND NITROGEN OXIDE TEST RESULTS

	Pre Long Term Neat Oil Tests		Post Long Term Neat Oil Tests	
	Low Load	High Load	Low Load	High Load
Load Range	31.4- 36.8	94.8- 97.8	39.1- 40.4	99.4- 110.9
Average Particulate Emissions, lbs/10^6 BTU	0.0661	0.121	0.0361	0.0532
Average Oxides of Nitrogen (as NO_2), lbs/10^6 BTU	0.172	0.216	0.153	0.210
Fuel Oil Ash Content, lbs/10^6 BTU	0.0168	0.0168	0.0016	0.0016
Fuel Oil Nitrogen Content, % by Weight	0.35	0.35	0.19	0.19
Excess Air, %	29.6	20.4	31.9	20.4

weight of nitrogen in the fuel and the percentage of flue gas excess air during each test series. Comparison of both high and low load particulate emissions during the Pre Neat and Pre Emulsified Oil Tests shows a decrease of 60% during the low load emulsified oil tests and a decrease of 75% during the high load emulsified oil tests. As explained in Section 4.2.1, there were some periods of unstable combustion during the Pre Long Term Neat Oil Tests. The fuel oil ash content was also lower for the Pre Long Term Emulsified Oil Tests. However, the difference in ash content does not equal the difference in particulate emissions. The excess air levels during the high load emulsified oil test was higher than during the high load neat oil test which would indicate that excess air was not trimmed enough during the emulsified oil tests. This could result in lower particulate emissions during the Pre Long Term Emulsified Oil Tests.

The results of the oxides of nitrogen tests indicate that the oxides of nitrogen emissions were lower for the Pre Long Term Emulsified Oil Tests. The Pre Long Term Emulsified Oil low load and high load oxides of nitrogen emissions were 28% and 14% less than the similar load Pre Long Term Neat Oil Tests. The lower fuel oil nitrogen content during the Pre Long Term Emulsified Oil Tests is consistent with the lower emissions.

4.2.3 Pre versus Post Long Term Emulsified Oil Tests

The results of the emission tests for the Pre and Post Long Term Emulsified Oil Tests are contained in Appendix H (see Tables H-5, 6, 7 and 8). Summaries of the emission test results are presented in Table 4-8. Table 4-8 also has the fuel oil ash content expressed as pounds per million BTU's of fuel fired, the percentage by weight of nitrogen in the fuel and the percentage of flue gas excess air during each test series. Comparisons of both high and low load particualte emissions show an increase of 123% and 96% during the Post Long Term Emulsified Oil Tests. Since the fuel oil ash content was nearly the same for the Pre and Post Long Term Emulsified Oil, this was not a factor in the difference in test results. The lower percentage of excess air in the flue gas of the

TABLE 4-8

SUMMARY OF PRE AND POST LONG TERM EMULSIFIED OIL TESTS, PARTICULATE AND NITROGEN OXIDE TEST RESULTS

	Pre Long Term Emulsified Oil Tests		Post Long Term Emulsified Oil Tests	
	Low Load	High Load	Low Load	High Load
Load Range	40.3-41.4	96.6-103.8	34.1-34.7	96.7-102.4
Average Particulate Emissions, lbs/10^6 BTU	0.0262	0.0297	0.0513	0.0664
Average Oxides of Nitrogen (as NO_2), lbs/10^6 BTU	0.124	0.177	0.105	0.180
Fuel Oil Ash Content, lbs/10^6 BTU	0.0072	0.0072	0.0073	0.0073
Fuel Oil Nitrogen Content, % by Weight	0.17	0.17	0.10	0.10
Excess Air, %	28.1	23.5	24.7	19.6

Post Long Term Emulsified Oil Tests indicates that the boiler's air level was trimmed more closely to stoichiometry during those tests. This would account for the higher particulate during the post tests.

The results of the oxides of nitrogen tests indicate that the oxides of nitrogen emissions were lower for the low load and slightly higher for the high load Post Long Term as compared to the Pre Long Term Emulsified Oil Tests. The Post Long Term Emulsified Oil oxide of nitrogen emissions for the high and low load tests were 2% higher and 15% lower respectively.

The lower fuel oil nitrogen content and lower excess air levels for the Post Long Term Emulsified Oil Tests are consistent with the lower emissions during the low load tests. The slightly higher oxide of nitrogen emissions during the high load Post Emulsified Oil Tests was unexpected and unexplainable. The higher fuel oil nitrogen content and higher excess air level during the comparable Pre Long Term Tests should have resulted in higher oxide emissions during these tests.

4.3 Boiler Tube Wastage and Fouling Results

Boiler tube wastage was determined quantitatively from analysis of test sections or windows which were welded into boiler tubes located in areas where maximum erosion and corrosion were anticipated. Under the guidance of Bigelow Boiler Company, the boiler's manufacturer, tube bank #1 was selected as the area of greatest erosion potential and tube bank #14 was selected as the area of greatest corrosion potential. The rationale behind the selection of tube bank #1 being the area of greatest erosion potential is that it is the area of highest gas temperature and therefore, greatest volumetric flow and velocity. The test windows in tube bank #1 were mounted 45 degrees from the axis of normal gas flow and were facing into the flow. The tubes in bank #14 were believed to have the greatest potential of showing the effects of corrosion because the flue gas temperature is minimum. These test windows were mounted on top of each tube facing the outlet damper. The test

windows were installed at the beginning and removed at the end of each long term testing period (see Table 1-1 for installation/removal dates). Metallographic hardness, thickness and visual analysis as well as chemical analysis of the test windows were performed on the test windows. Section 2.7.2 contains the complete details of the test window locations in the boiler and their analyses.

Boiler tube fouling was examined by analysis of the fireside deposits on the tubes in the vicinity of the test windows. These samples were collected after each long term test. The analyses performed were semi-quantitative spectrographic analysis for metallic elements, quantitative analysis for carbon and sulfur, pH and qualitative analysis for chloride, sulfate and carbonate.

4.3.1 Parent Tube Material Characteristics

Since the test window analysis were to be compared with samples of the parent metal to determine the extent of any corrosion and/or erosion during the Long Term Tests, it was first necessary to characterize the parent tube material. The analysis determined that the test windows had been cut from two different parent materials. Both parent materials met the requirements of ASTM A106 seamless carbon steel pipe for high temperature service with the exception of the silicon content, which was low in both materials. The difference in the parent materials was identified as one being Grade A, while the other was Grade B. The Grade A material thickness was 0.117" and the Grade B material thickness was 0.114". The complete report on the characterization of the parent materials is included in Appendix I and is dated July 24, 1981.

4.3.2 Long Term Neat Oil versus Long Term Emulsified Oil

Visual examination of the test windows removed after the long term neat oil tests showed severe melting damage and thermal distress, due to use of any oxy-acetylene cutting torch to remove the test windows. The surfaces of the windows were also damaged by grinding. Unfortunately, the thermal distress destroyed anything

which might have been present of a significant metallographic nature and any reduction in thickness was more likely due to grinding rather than corrosion or erosion. Therefore, no information whatsoever could be obtained from the test windows for the long term neat oil tests. Fortunately, this problem did not impact the program results because these measurements were to be a baseline for comparison of wastage during the emulsified oil tests and, as will be explained, there was no measurable wastage of the emulsifier fuel tube samples. The report on the long term neat oil test windows is included in Appendix I and is dated July 24, 1981.

Based on the problems encountered with the test windows from the long term neat oil tests, an alternative method of test window removal was developed. The procedure included corner-drilling and sawing out of the test pieces. No problems were encountered with this procedure and the report on the long term emulsified oil test windows is contained in Appendix I and is dated May 3, 1982. The tube windows numbered 2, 3 and 4 were removed from the second, third and fourth tube row from the access door in the #14 tube bank. The tube windows numbered 7, 8, 9, 10, 11 and 12 were removed from the seventh, eighth, ninth, etc. tube row from the right furnace wall in the #1 tube bank. The metallographic analysis of the samples found that none of the tube window specimens had been attacked or distressed on the fireside. Also, no evidence of significant metallurgical transformation was observed in any of the specimens. Thus, there was no measurable erosion or corrosion during the long term emulsified oil test which lasted nine (9) months and twenty-one (21) days (June 30, 1981 through March 21, 1982). The emulsified fuel oil burned during the entire test period was 520,470 gallons which, based on six (6) percent water by weight is equivalent to 491,600 gallons of neat oil.

Scrapings of the fireside deposits in the vicinity of the test windows were collected upon conclusion of the long term neat oil and emulsified oil tests. The analysis of the fireside deposits are contained in the reports dated July 24, 1981 (long

term neat oil tests) and May 3, 1982 (long term emulsified oil tests) in Appendix I. The results of the analysis of the tube scrapings are summarized in Table 4-9. The following observations are relative to the composition of the scrapings:

* carbon comprised approximately half of the deposits on the tube bank by the uptake for both the neat oil and emulsified oil tests which indicates some incomplete combustion during each test series.

* carbon content of the furnace generating tubes was much less during the emulsified oil tests (1%) than the neat oil tests (5%) indicating more complete combustion during the emulsified oil tests.

* sulfur content of the emulsified oil deposits was slightly greater on both the furnace tubes and the outlet tubes which is consistent with the higher average percentage of sulfur in the fuel oil during the emulsified oil tests (0.68% sulfur) than during the neat oil tests (0.42% sulfur).

* the fireside deposits from the emulsified oil tests had higher vanadium content than from the neat oil tests. This was consistent with the higher average concentration of vanadium in the fuel oil (84 ppm for emulsified oil and 54 ppm for neat oil tests).

* the sodium content of the deposits of the neat oil tests was higher than the emulsified oil tests. This was not consistent with the higher average concentration of 53 ppm sodium for the emulsified oil tests versus 28 ppm sodium for the neat oil tests. It is believed that improved atomization during the emulsified oil tests resulted in a finer or dryer sodium sulfate bearing fly ash which had either a lower deposition rate or was more effectively removed during soot blowing.

* the aluminum, nickel, iron and molybdenum content of the fireside deposits are believed to reflect their concentrations in the fuel oil. The fuel oil however was not analyzed for these metals.

TABLE 4-9

RESULTS OF ANALYSIS OF BOILER TUBE SCRAPINGS
AFTER LONG TERM NEAT OIL AND EMULSIFIED OIL TESTS

ELEMENT/COMPOUND	AMOUNT ON GENERATING TUBE BANK NO. 1[A]		AMOUNT ON GENERATING TUBE BANK NO. 14[B]	
	NEAT OIL	EMULSIFIED OIL	NEAT OIL	EMULSIFIED OIL
Carbon	5.45%	1.01%	50.66%	46.36%
Sulfur	10.05%	11.65%	5.87%	7.84%
Vanadium	5-15%	>15%	5-15%	>15%
Sodium	>15%	1-5%	1-5%	0.1-1%
Sulfate	>15%	>15%	5-15%	>15%
Aluminum	1-5%	1-5%	5-15%	1-5%
Nickel	1-5%	5-15%	5-15%	5-15%
Iron	1-5%	0.1-1%	>15%	1-5%
Molybdenum	1-5%	0.1-1%	<0.1%	<0.1%
Calcium	0.1-1%	1-5%	1-5%	5-15%

A - Tube bank No. 1 is located in furnace.

B - Tube bank No. 14 is located by the uptake damper

* the higher calcium content of the deposits of the emulsified oil tests was believed to be due to the calcium in the municipal water which was used for the water-in-oil emulsion. The average calcium concentration of the water was 7.8 ppm.

Heavy slagging occurred during the long term emulsified oil test and samples were collected for semi-quantitative spectrographic analysis. The analysis found that the slag contained more than 15% vanadium and 5 to 15% nickel. It is believed that the higher slagging rate during the emulsified oil tests than during the neat oil tests was due to the higher vanadium content of the fuel oil. The slagging on the furnace was confined to the refractory walls and floor and there wasn't any evidence of slagging on the water wall or generating tubes.

Along with the scrapings from the #1 and #14 tube banks, a sample of the surface deposits on the #6 tube bank (back pass) was collected and analyzed to look at the variability of the deposits in the flue gas path through the boiler. The analysis indicated the following:

* carbon content of the deposits increased from 1% in the #1 tube bank (furnace) to 16% in the #6 tube bank (back pass) to 46% in the #14 tube bank (boiler outlet).
* sulfur content of the deposits increased from 11.7% in the #1 tube bank to 14.6% in the #6 tube bank then decreased to 8% in the #14 tube bank.
* large concentrations ($>$ 15%) of vanadium and sulfate were found in all three locations.
* moderate concentrations (5-15%) of nickel were found in all three locations.
* the concentration of calcium in the deposits increased from small (1-5%) in the #1 and #6 tube banks to moderate (5-15%) in the #14 tube bank.

The above variations in the contents of the deposits are believed to be due to the different operating temperatures occurring

at the various locations in the boiler with the highest temperature in the furnace and the lowest at the boiler outlet.

4.4 Long Term Test Results

The purpose of the long term tests was to determine any differences in boiler performance degradation and the wastage over an extended period for emulsified oil compared to neat oil. The two main factors which were believed to influence the amount of boiler fouling and tube wastage were the boiler firing rate or load and the duration of the test. Since the U.S.C.G. Academy boiler primarily provides heating service, its load is most greatly impacted by the outside temperature. The long term tests were therefore designed to encompass the winter months (November to March) of one heating season per fuel. Table 4-10 presents the duration of the tests plus the fuel oil fired and the feed water supplied to the boiler. The data in Table 4-10 shows that there were similar quantities of fuel oil burned and feed water supplied during the long term neat oil and emulsified oil tests. The difference in test duration is a result of differences in steam demand during the winter and summer months.

TABLE 4-10

LONG TERM TEST PERIODS AND DURATION,
FUEL OIL USEAGE & FEED WATER SUPPLIED TO TEST BOILER

	Long Term Neat Oil Test	Long Term Emulsified Oil Test
Test Period	9/18/80 - 5/3/81	6/30/81 - 3/21/82
Test Duration	8 months & 14 days	9 months & 21 days
Fuel Oil Used, Gallons	479,980	520,470 (491,840[A])
Feed Water Supplied[B], Gallons	6,879,730	7,017,730

A - equivalent gallons of neat oil based on 5-1/2% water by volume in emulsion

B - not corrected for blowdown

Prior to each long term test the boiler was:

* cleaned and repaired
* inspected
* fitted with tube material test windows
* tuned
* tested to determine efficiency and flue gas emissions

Upon completion of each long term test, the boiler was:

* tested to determine efficiency and flue gas emissions
* inspected
* relieved of tube material test windows

The differences in performance during the long term tests are considered to be qualitative rather than quantitative and the evaluation consisted of the boiler inspection reports and the time interval necessary between soot blowings.

The boiler inspection reports for before and after the long term neat and emulsified oil test periods are included as Appendix J.

The before long term neat oil test inspection (August 20-21, 1980 and September 8, 1980) indicated that the fireside was in good condition with floor and knee wall cracks patched. The burner throat tiles were true and in good condition. Burner registers were in good condition with loose register tubes. The diffusers were lightly slagged with free slots and the burner tips were new for the test. The water wall tubes were cleaned to bare metal with a light coating of brown oxide, due to steam cleaning. The generating tubes had sintered deposits over lower 25% and a light coating of soot and liquid carbon destructor, which was applied to aid the burn-off of soot. The boiler waterside had normal physical appearance with localized pitting at belt line of steam drum. Steam drum was free of mineral deposits with slight oxidation of metal (80% bare metal). Water drum and water wall header were also clean, with only slight oxidation.

The after long term neat oil test boiler inspection (May 15,

1981) indicated that the fireside was in poor condition with the knee walls in need of replacement. The burner throat tiles were true and in fair condition. The burner registers were in fair to poor condition with one register sticky and difficult to open. The diffusers were slagged with slots open and the tips were in fair condition with miscellaneous scratches. The water walls in the entire furnace had one-sixteenth inch to one-eighth inch (1/16" to 1/8") thick layer of brown powdery deposits which could be easily scraped off. The left water wall tubes had evidence of flame impingement, as did the floor in front of the left burner. The generating tubes had one-sixteenth inch to one-eighth inch (1/16" to 1/8") thick layer of brown powdery deposits in the furnace and one-eighth inch to one-fourth inch (1/8" to 1/4") thick layer of brown powdery deposits by the gas damper. The steam drum, water drum and water wall header had thin (approximately 1/64") soft, uniform layer of baked-on sludge which could be easily removed to bare metal.

The before long term emulsified oil test inspection (June 3, 1981) indicated that the fireside was in good condition with the right and left knee walls rebuilt and seal caps replaced. The burner throat tiles were trued and resurfaced. The burner registers were cleaned and fitted with new operating rings. Register #1 had new shaft and arm. Both registers operated freely. The burners were cleaned and brand new tips and plugs were available for the next test series. The water wall tubes and generating tubes were cleaned to bare metal. The boiler fireside and watersides were clean and in a similar condition to the pre long term neat oil tests.

The post long term emulsified oil test inspection (April 1, 1982) indicated that the fireside was in good structural condition except that the refractory transition in front of the center step in the floor separated one and one-half inches (½") toward the front wall. The entire floor was glazed over with heavy accumulations of slag against the rear wall. The surfaces of the knee walls were completely glazed with a clinker 1' x 6" x 4" thick on the

left knee wall and a clinker 1½' x 10" x 2" thick on the right knee wall. The rear knee wall had heavy slagging. The lower front wall was 80% glazed. The burner throat tiles were true and in fair to good condition. The burner registers were in good condition. These registers were not the same as at the beginning of the long term emulsified oil tests because of repeated jamming problems. The original registers were replaced on December 16, 1981 with registers from boiler number 2. The burners and diffusers were in fair to good condition with the oil tubes lightly coked. The tips were in fair to poor condition with numerous scratches. The water wall tubes had 25% covering of hard scale which was removable by wire brushing. The generating tubes had greyish-black easily removable surface deposits of approximately one-sixteenth inch to one-eighth inch (1/16" to 1/8") in thickness. The surface deposits by the gas damper were approximately one-sixteenth inch (1/16") thick. The condition of the boiler's waterside was good with no chemical cleaning required. A thin film of whitish-grey-brown deposits could be seen on the tube surfaces. This film was easily removable by pressure hose washing.

The boiler inspections showed that the boiler was essentially in the same physical condition and state of cleanliness at the beginning of each long term test. The boiler cleanliness at the end of the long term emulsified oil test was found to be slightly cleaner than at the end of the long term neat oil test.

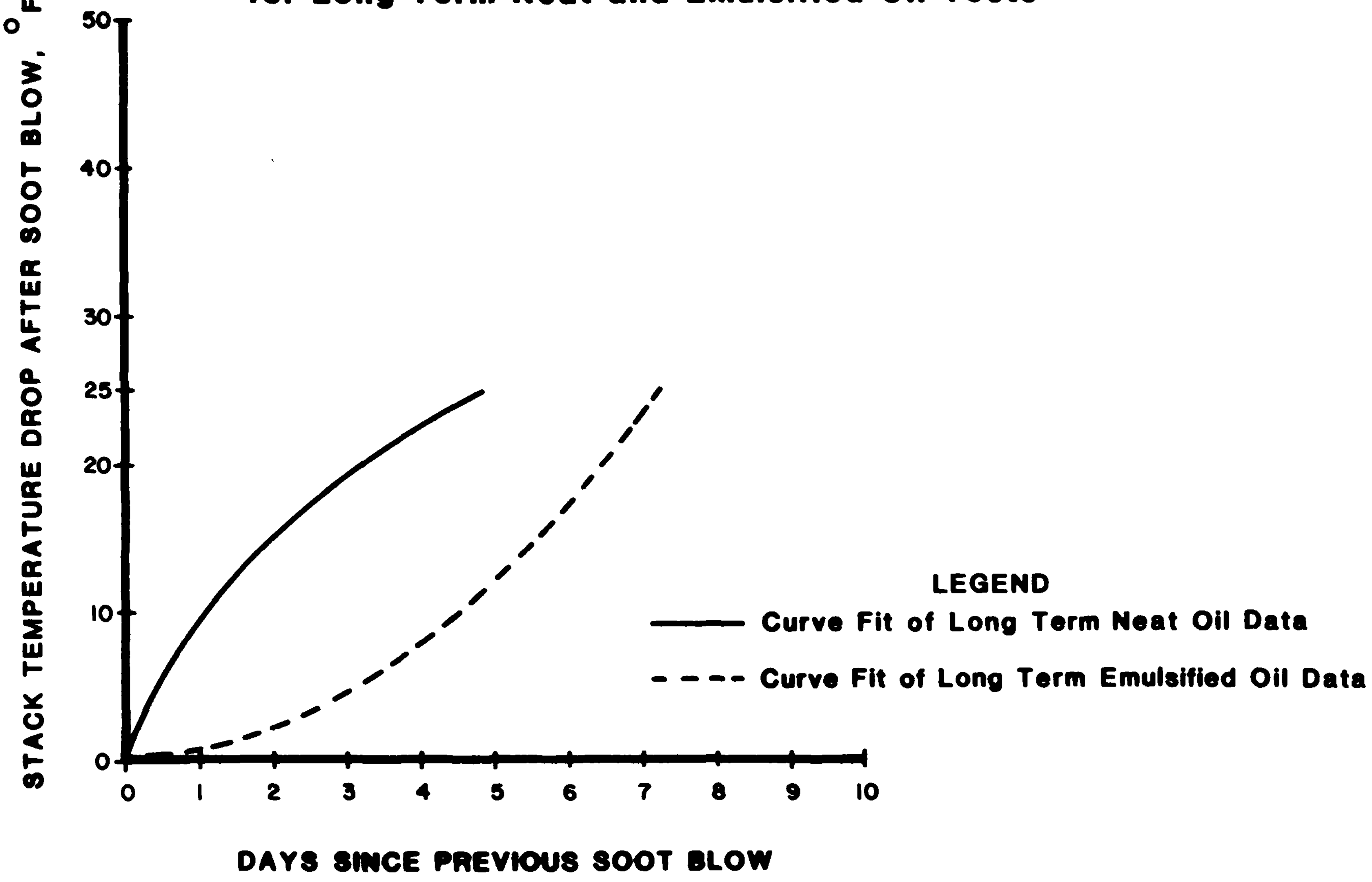
An additional method of evaluation of the emulsifier was based on the belief that if the emulsifier enhanced atomization and therefore improved the combustion efficiency, it should be possible to increase the time interval between soot blowing. Discussions with the test boiler's manufacturer identified a 25°F increase in flue gas temperature over the clean boiler temperature as a reasonable criteria on which to base the need for soot blowing. Therefore, graphs were drawn of the flue gas temperature versus boiler load from the data collected during the pre long term neat and emulsified oil tests. Using the rise in stack temperature as a gauge for

judging when soot blowing is necessary is complicated because flue gas temperature is also dependent upon three variables other than reduced heat transfer. These three variables are: boiler load, excess air and operating equilibrium (for example, when a boiler is operating at high load and then the load drops off, the flue gas temperature will be higher than normal until the system returns to equilibrium). The U.S.C.G. watchstanders were instrumental in instituting a practical approach to the problem. First, it was decided to determine if soot blowing was needed each day during the midnight to zero-eight-hundred watch in January and February. This was believed to be the period during which the boiler load is most constant. The stack temperature and load were noted and compared with the graph values to determine if soot blowing is required. If required, a special print-out on the data logger was made prior to, and after, the completion of soot blowing. This data was analyzed based on the flue gas temperature drop after soot blowing and care was taken to use only data in which the excess air levels were similar before and after the soot blowing. It was not always possible to have similar loads before and after soot blowing and where necessary, the data was corrected using the temperature difference for the different loads based on the pre long term test data. The data is presented in Figure 4-7 and the curves represent power curve fits of the data. From Figure 4-7 it is shown that the sequence between soot blowing can be longer (seven (7) days versus five (5) days) for the emulsified fired fuel. This is as expected, based on the lower particulate emissions for the emulsified oil tests.

A benefit that was derived from the soot blowing tests was that the test boiler routinely had soot blown twice per day. This amount of soot blowing was determined to be unnecessary and the interval between soot blowing was increased to every three (3) to five (5) days for the neat oil tests. This also points out the value of boiler instrumentation which allows variables to be sorted out and changes made to allow more economical operation. A calculation based on design data on the Copes-Vulcan soot blowers and

Figure 4-7

Stack Temperature as a Function of Days After Soot Blowing for Long Term Neat and Emulsified Oil Tests



the U.S.C.G. soot blowing procedure indicates that approximately 400 pounds steam is used for each complete soot blow. This equates to about three and one-half ($3\frac{1}{2}$) gallons of fuel oil expended per soot blow.

4.5 Discussion of Results

4.5.1 Efficiency Tests

During the closely controlled pre and post long term and baseline efficiency tests, an attempt was made to control and monitor all variables which could influence the test. Upon analysis of the pre long term emulsified oil test results, it was noted that the efficiency was slightly less for these tests than the averaged baseline neat oil tests. It was also noted that the particulate emissions for the pre long term emulsified oil tests was much less than for either the pre or post long term neat oil tests. Excess air is one variable that affects both the efficiency and emissions, and this type of result indicates that the excess air could have been further trimmed during the pre long term emulsified oil tests. The closer the boiler is run to stoichiometric, low excess air, the better will be its efficiency because the losses of heat out the stack will be minimized. Boilers are routinely tuned for maximum efficiency by trimming back on the excess air until a point is reached at which excess air cannot be further lowered without incomplete combustion and the resulting smoking of the boiler. This point is a fairly fine point. During the conduct of all tests, the opacity of the boiler was observed and the excess air trimmed to obtain approximately twenty percent (20%) before a test was begun. The flame condition in the furnace was also observed to assure that it indicated low excess air (no sparklers and a hazy orange appearance) and that there were no signs of flame impingement. During the pre long term emulsified oil test this procedure was followed, however, certain characteristics of the emulsifier, the fuel system and the boiler operation resulted in the requirement for a decision as to what level the air should be trimmed in the boiler. It was noted while trimming the excess air that the opacity would change

coincident with the making of an emulsion by the emulsifier. Closer inspection into the phenomenon revealed that the fuel oil pump discharge pressure increased slightly when the emulsion was being made. Since the boiler's fuel oil system was set-up with a constant opening of the fuel oil regulating valve to assure a constant load, every time the pressure increased, the fuel oil supply was increased slightly and if the boiler air had been trimmed too closely, the boiler would smoke. Therefore, when the boiler was set-up prior to each pre long term emulsified oil test, the air was trimmed to a point at which the boiler would not smoke excessively when making an emulsion. Consequently, when the emulsifier was not making an emulsion, it was not trimmed to its minimum excess air level with a resulting loss in efficiency. During the post long term emulsified oil test, the above pressure fluctuation problem had been identified and the air was trimmed further than during the pre long term test. The higher efficiency at boiler loads less than 45% for the post long term emulsified oil tests correlate with the lower excess air levels during these tests. The emissions during the post long term test were also more in agreement with those of the post long term neat oil tests.

It must be kept in mind when evaluating the efficiency results that the purpose of the emulsifier is to increase combustion efficiency by improving atomization of the oil droplets. Since atomization in the test boiler was adequate, as evidenced by the ability to reduce excess air to near design levels, there was little potential for improvement to be made. In addition, when water is admitted to the boiler, it represents a heat loss out of the boiler due to the water vapor exhausting from the boiler at the flue gas temperature. Therefore, any improvements in efficiency of the boiler for the emulsified oil tests had to be in excess of the 0.4% heat loss due to the 6% water content in the oil.

4.5.2 Emission Tests

The discussion in the previous section (4.5.1) is applicable to the emission test results and the relationship of excess air,

efficiency and emissions should be considered when evaluating the emission results.

Graphical comparisons of the particulate and nitrogen oxide emissions are presented in Figures 4-8 and 4-9. For comparison purposes, the highest emission level is labeled 100% and all other levels are compared to the highest level. This is somewhat misleading in the case of the particulate results because the highest level during the Pre Long Term Neat Oil Tests was believed to be a result of an instability caused by using the Hagan Automatic Combustion Control System during those tests. The Hagan system responds to changes in boiler drum pressure and either increases or decreases the combustion air flow in response to changes in load. The fuel flow then follows the air flow until the fuel and air flow are adequate for the boiler load and the steam pressure is constant. Smoking can occur however when the boiler load decreases and the drum pressure increases, causing the Hagan system to cut back the boiler combustion air flow rate. Depending upon the magnitude of change in the air flow and the cushion of air flow above that required, the boiler smokes until the decrease in air flow is sensed and the fuel flow is reduced. The boiler Hagan system was set on automatic during the Pre Long Term Neat Oil Tests and the boiler load was manually controlled with the dump valve to maintain a constant signal from the Hagan system to the combustion air dump. Since part of the boiler load was being utilized by the Academy services and part was being dumped, changes in the Academy load resulted in changes to the boiler load. Although these changes were compensated for, the high particulate emissions were the result of insufficient air during some of the load swings. The boiler combustion control system was set on manual for all pre and post long term tests except the Pre Long Term Neat Oil Tests. In those tests, with the combustion control on manual, the dump valve was opened and shut to maintain the boiler drum pressure.

Figure 4-8
Comparison of Particulate Emissions

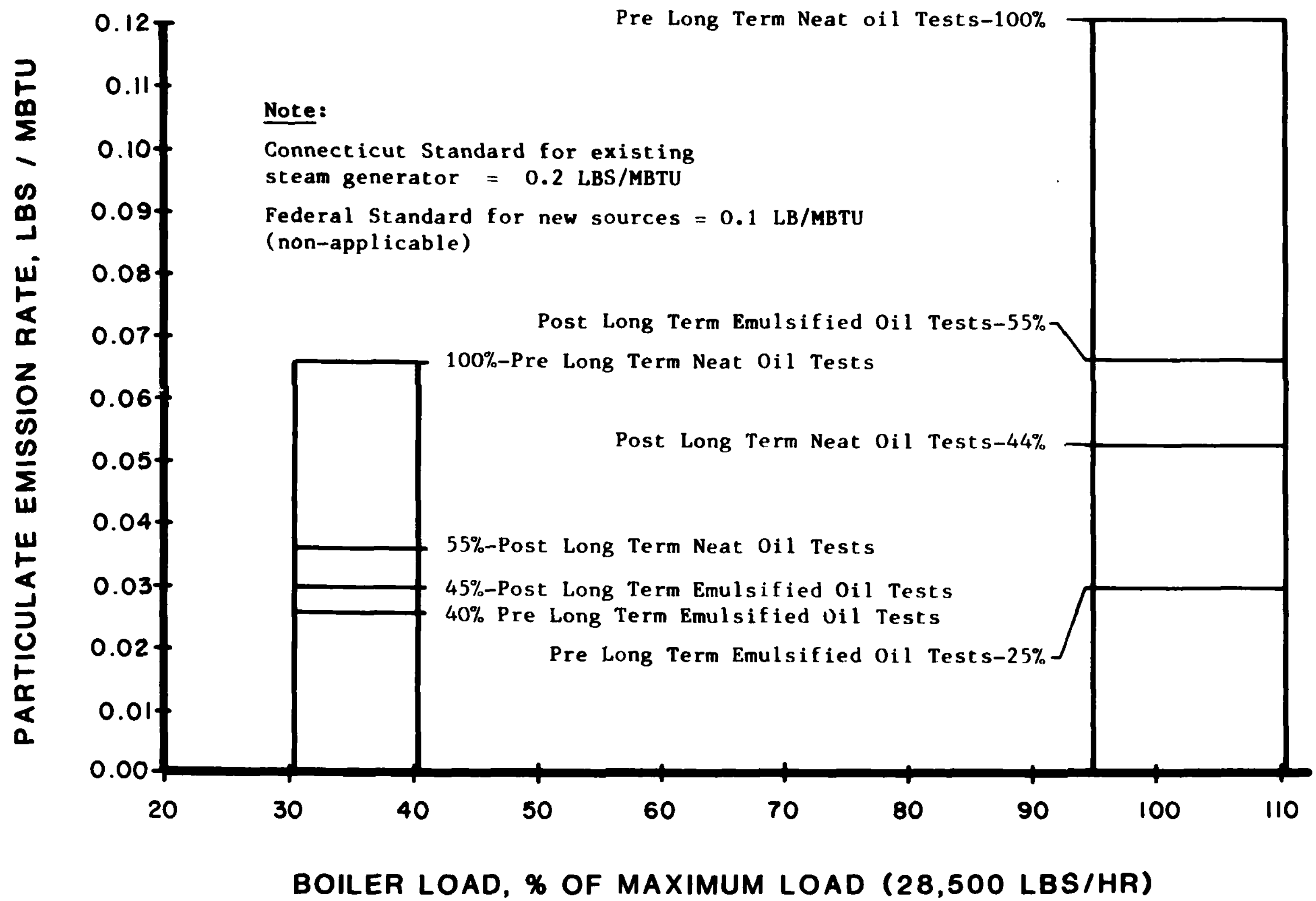
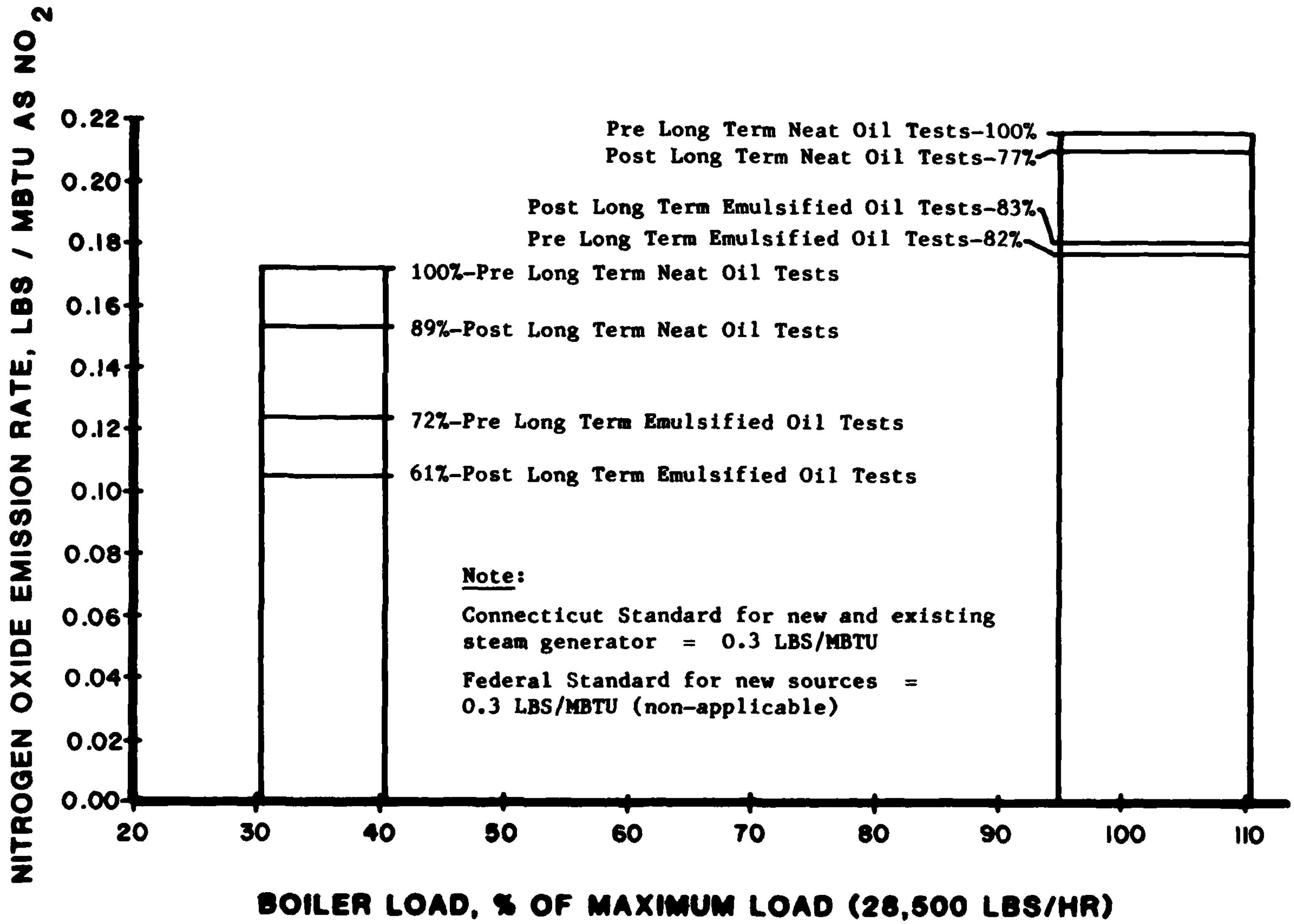


Figure 4-9

Comparison of Nitrogen Oxide Emissions



5.0 ECONOMIC ANALYSIS

5.1 Introduction

The purpose of the economic analysis is to determine if there are sufficient savings in the operating costs of the test boiler to justify the purchase and operation of a low energy emulsifier. The analysis is based on test boiler loads for a typical heating season at the U.S.C.G. Academy. The analysis considers the savings due to differences in fuel consumptions, longer intervals between soot blowing and the emulsifiers operating and maintenance expenses.

5.2 Analysis Methodology

The following approach was used in the economic analysis:

1. The average boiler load was calculated for each month from October through March for both the long term tests.
2. The average fuel oil heat content was calculated from the fuel analysis for the long term neat oil tests.
3. The average heat absorbed by the feed water was calculated from all the pre and post long term efficiency test data.
4. A linear change of boiler performance was assumed from each pre long term to each post long term efficiency test and this change was used to calculate an adjusted boiler efficiency for neat oil and emulsified oil firing for each month.
5. The adjusted boiler efficiency, boiler load, fuel oil heat content and the heat absorbed by the feed water was used to calculate the fuel oil consumed for each month from October through March for neat and emulsified oil.
6. The fuel oil consumed for each month was summed to determine the total fuel oil for the neat and emulsified oil firing. The difference in gallons was then multiplied by the cost per gallon of the fuel oil to determine the total difference in cost between the boiler burning neat oil and burning emulsified oil.

7. The total heating season fuel cost was less for emulsified fuel than for neat oil, the difference being greater than the heating season operating cost for the emulsifier (see Section 3.7). Therefore, the emulsifier operating cost was subtracted from the difference in fuel cost.

8. Finally, the frequencies of soot blowing of five (5) days (neat oil) and seven (7) day (emulsified oil) were used to calculate the difference in cost due to reduced soot blowing during the emulsified oil tests. The total savings was calculated for the heating season and added to the difference in fuel cost.

5.3 Economic Analysis Results

Based on the information in Table 5-1, the sum of the estimated difference in oil useage over the heating season amounts to 1,526 gallons saved by using the emulsifier. The U.S.C.G. Academy cost per gallon of oil during May 1982 was $0.91.

TABLE 5-1

SUMMARY OF EXPECTED HEATING SEASON DATA FOR COST ANALYSIS

Month	Average % Load	Neat Oil Blr Eff.,%	Emuls. Oil Blr. Eff.,%	Est. Difference in Oil Useage, Emul.-Neat Oil, Gal/Month
October	25	80.1	78.2	1203
November	38	79.1	78.6	432
December	46	78.6	78.8	-248
January	56	77.9	78.2	-420
February	45	78.2	78.7	-482
March	41	78.3	79.1	-796
April	29	79.1	80.9	-1215

Thus, the cost savings due to fuel oil saved would be $1,389 per heating season. This, however, was adjusted to account for the

operating cost of the emulsifier (Section 3.7) which amounted to $1,068 for the heating season. The savings associated with reduced soot blowing were $38.00. Therefore, the total savings per heating season is $359.

When interpreting these results, it must be remembered that the analysis uses the efficiencies as measured in the pre and post long term efficiency tests which were adjusted to account for deterioration. It would have been preferable to use the data during the long term tests as a basis for the analysis. However, the pounds steam generated per million BTU's fired was sometimes greater and sometimes less during the emulsified oil tests as compared to the neat oil tests. The boiler loads, frequency and magnitude of load changes, the combustion control system and the diligence of the operator all account for the variability seen. Therefore, an idealized case is presented and should only be considered as a guide. It is believed that these sort of results would occur at the U.S.C.G. Academy with modern combustion control systems in which excess air is minimized during all operations.

The difference in the fuel oil useage was also determined for the April load using the efficiencies from the preliminary neat oil test and the post long term neat oil test. Since the boiler cleanliness was similar for the test point, the comparison gave an indication of the amount that the boiler was out of tune. Based on the $0.91/gallon cost for fuel oil, the estimated operating cost differential for the month was calculated to be $1,470. This indicates the value of boiler tuning. The main benefit of the tuning was derived from the burner manufacturer service engineer who checked the burner's condition and orientation. It was learned at this time that dimensional information in the burner manufacturer's instruction manual for the test boiler was incorrect. By setting up the burner in accordance with the service engineers specifications, it was possible to greatly reduce the boiler's excess air level which resulted in a lower stack temperature, and thus, a higher boiler efficiency.

To determine the difference due to cleaning and tuning, the

efficiencies from the preliminary and pre long term neat oil tests were used to calculate the estimated fuel oil consumption for the month of October. Based on the $0.91/gallon fuel cost, the operating cost differential for the month was calculated to be $2,450. Attributing this amount to cleaning and tuning, and considering that $1,470 could be attributed to tuning alone, the cleaning accounts for an estimated $980 decrease in operating expense for the month of October using the criteria presented earlier in this section. The cost of cleaning the firesides and tuning was approximately $2,000 and could be justified by the estimated savings in October alone. Application of this finding to other boilers is not advised because it depended upon the test boiler's state of cleanliness and tuning. However, it is not believed that the condition of the test boiler before cleaning and tuning was atypical of industrial boilers. The above analysis points out the necessity of having and maintaining sufficient calibrated instrumentation to allow for determination of the extent of efficiency loss and therefore, the increase in operating expense at any particular point in time.

6.0 CONCLUSIONS AND RECOMMENDATIONS

This section presents a summary of conclusions and recommendations developed from the foregoing detailed test results and economic analysis. As discussed in Section 1.0, these results and conclusions are directly applicable to the test boiler at the U.S. Coast Guard Academy. While they may be relevant to similar boiler installations using comparable fuels they should not be considered applicable to all boilers.

6.1 Efficiency Improvements/Penalties

6.1.1 Cleaning and Tuning

The following conclusions are evident relative to boiler cleaning and tuning:

* Comparison of preliminary and averaged baseline neat oil efficiency test results (see Table 4-3) shows that cleaning and tuning increased boiler efficiency a maximum of 2.9% (76.9% to 79.8%) at the 30% boiler load. The efficiency was increased over the entire load range and with the minimum increase of 0.6% (77.2% to 77.8%) at the 70% boiler load.

* A comparison of preliminary and post long term neat oil test data was used as an indication of the benefit of tuning because the boiler was believed to be in approximately the same state of cleanliness at the time of each of these tests. This comparison shows that 60% of the recovered efficiency was due to tuning and 40% was the result of cleaning.

* Acid cleaning of the boiler's waterside was not necessary over the test period. The soft surface deposit was easily removed by a pressured water stream. This indicates that the boiler chemicals were keeping any deposits from forming hard scale on the tube surfaces which could lead to overheating and failure. It therefore appears that annual waterside cleaning using high pressure water should be adequate to maintain waterside cleanliness for many years, provided the boilers

chemical water testing and treatment are performed religiously.

6.1.2 Emulsified Oil versus Neat Oil Firing

The differences in efficiencies at the beginning and end of the long term neat oil and emulsified oil tests was only slight and therefore, on a basis of efficiency alone, there appears to be only a slight benefit to be gained by firing an emulsion. That only a slight benefit was seen is not surprising, in that the neat oil-fired tuned boiler excess air level was able to be reduced to the point where the furnace was noted as being filled with a dark orange flame having a lazy, rolling appearance indicating minimal excess air. The lack of a larger increase in efficiency improvement using an emulsion is therefore believed to be due to the steam atomized burners ability to fire close to the designed air level without excessive smoking. Therefore, although it was possible to trim the excess air a little further while firing an emulsion, the amount of efficiency gain through reduced excess air and stack temperature stack losses just barely offset the efficiency loss through increased stack losses from the latent heat in the water introduced by the emulsifier being lost out of the stack. The loss in boiler efficiency associated with the water in the fuel oil amounts to approximately 0.4% based on burning a 6% by weight water in oil emulsion. The efficiency gain due to the reduction in unburned carbon leaving the boiler as particulate during the emulsified oil tests must also be considered. However, when the loss is calculated it is only a maximum of 0.1% for the worst case during the neat oil tests, and therefore, not a significant gain in efficiency.

Thus, the small gain in efficiency measured during the emulsified oil tests is consistent with the other observed data and supported by the fireside condition of the boiler at the end of the emulsified oil test. It is therefore concluded that the combustion efficiency of the steam atomized burner was nearly 100% on neat oil at the near design excess air level and that improvement in atomization due to the firing of an emulsion could not produce

substantial gains in efficiency because there was a minimum potential for improvement.

6.2 Particulate and Nitrogen Oxide Emissions, Neat versus Emulsified Oil

6.2.1 Particulate Emissions

The results show that the particulate emission rates were less for the boiler while firing emulsions than while firing neat oil. Also, that the emission rate was higher for the high load tests than the low load tests. The higher emissions during the high load tests are believed to be due to the flame hitting the furnace walls during these tests, as indicated by the evidence of flame impingement during the boiler inspections. As stated previously, the pre long term neat oil tests were run with the combustion control on automatic and thus caused some instability which resulted in the higher emission rates during these tests.

The inverse relationship between excess air and particulate emissions was consistent when examining the data other than the pre long term neat oil tests. The particulate emissions for these other tests are greater in all cases when the excess air was lower. It therefore is not believed that any increase in emissions resulted over the duration of either long term test and that comparison should be made with the post long term neat oil test emissions to determine the differences between neat oil and emulsified oil firing. On this basis, the high and low load pre long term emulsified oil tests were 57% and 73% of the post long term neat oil tests. The high and low load post long term emulsified oil tests were 125% and 82% of the post long term neat oil tests. These results indicate that more complete combustion at low loads is possible with emulsified oil firing in that the particulate emissions were lower for the low load pre and post long term emulsified oil tests even though the excess air levels were lower.

6.2.2 Nitrogen Oxide Emissions

The test results indicate that in all cases the nitrogen oxides

emission rate was less for emulsified oil than for the neat oil tests. These results, however, are believed to be primarily dependent upon the fuel oil nitrogen content. Table 6-1 sumarizes the entire nitrogen oxide emission results plus the excess air levels during the tests.

TABLE 6-1

SUMMARY OF NITROGEN OXIDE EMISSION RESULTS

	LONG TERM NEAT OIL TESTS				LONG TERM EMULSIFIED OIL			
	PRE TEST		POST TEST		PRE TEST		POST TEST	
	LOW LOAD	HIGH LOAD	LOW LOAD	HIGH LOAD	LOW LOAD	HIGH LOAD	LOW LOAD	HIGH LOAD
Average Oxides of Nitrogen (as NO_2), lbs/10^6 BTU	0.172	0.216	0.153	0.210	0.124	0.177	0.105	0.180
Fuel Oil Nitrogen Content, % by Weight	0.35	0.35	0.19	0.19	0.17	0.17	0.10	0.10
Flue Gas Excess Air, %	29.6	20.4	31.9	20.4	28.1	23.5	24.7	19.6

The results also show that the nitrogen oxide emission rates were higher for the high load tests than the low load tests. This is believed to be due to the higher flame and furnace temperature at the high load tests, resulting in a higher yield for the reaction of nitrogen in the combustion air with the oxygen in the combustion air.

6.3 Tube Fouling

Less fouling occurred during the long term emulsified than the long term neat oil tests based on the higher efficiencies at the conclusion of the long term emulsified oil tests (see Figure 4-6). The lower fouling rate for the emulsified oil tests is

supported by the analysis of the scrapings from the generating tubes in which a much lower (1% emulsified oil versus 5% neat oil) carbon content was found. That difference in tube fouling was small and is supported by the boiler fireside inspections which found only slight difference in the tube surfaces for the end of neat and emulsified oil tests.

6.4 Tube Erosion/Corrosion

There was no measurable erosion or corrosion of the boiler tube surfaces due to firing an emulsified oil for a period of nine (9) months and twenty-one (21) days during which 520,470 gallons of emulsified fuel oil were burned. Although there was no data from the neat oil tests with which to compare the tube erosion/corrosion rates, it is believed that there would not have been any measurable tube deterioration because of the normal longevity of the boiler tubes which normally do not fail due to erosion or corrosion.

6.5 Soot Blowing Requirements

The data indicates that the soot blowing interval could be increased from five (5) to seven (7) days when burning an emulsion. This is believed to be due to the more complete combustion from better atomization of the emulsified oil.

6.6 Economic Analysis

Based upon the net savings per heating season of $359 for burning an emulsion (see Section 5.3), the purchase price of the emulsifier of $12,650 is not considered economically attractive on the basis of a simple payback period of approximately 35 years.

Further, it appears that no economic benefit would be derived as a function of extended fireside cleaning interval due to emulsion firing as boiler cleanliness in each case was almost comparable on the basis of the limited test periods.

6.7 Alternative Boiler Modifications at U.S.C.G. Academy

Three methods of improving boiler and power plant operating efficiency as alternatives to water-in-oil emulsion firing appear to

be potentially advantageous and are therefore presented here. These alternative methods are based on observations and data collected throughout the entire test program. The three approaches are identified as: the replacement of the existing burners and combustion control with a system allowing firing at low excess air levels; the addition of economizers to the existing boilers; and the addition to, or replacement of, one of the existing boilers with a lower capacity packaged boiler. Each of the alternatives which will be discussed has the potential to reduce fuel oil costs at the facility. However, in-depth engineering and economic analyses are necessary to determine precisely their economic merit, specifically with respect to payback periods. While not an in-depth analysis, the following provides some preliminary data.

The replacement of existing burners and combustion controls with a system allowing continuous firing at low excess air levels of approximately 7% would improve boiler efficiency by reducing the heat lost up the stack. Preliminary estimates indicate a reduction in fuel consumption of approximately 2% at low load (approximately 40% load) and 0.6% at full boiler load (100%). However, it may not be possible or practical to maintain the low excess air levels over the boiler's operating range. If low excess air burners were to be seriously considered, it would be advantageous to have a modeling study conducted to determine if changes would be required to the windbox and furnace configurations to achieve the low excess air levels over the extreme load range encountered at the Academy.

The fitting of the U.S.C.G. Academy boilers with economizers has a good potential for boiler efficiency improvement, especially at high loads. Economizers tranfer some of the heat from the flue gas to the feed water and thereby reduce flue gas heat losses. Preliminary calculations indicate a potential fuel savings of 3% at low load (40%) to 5% at full load (100%). An analysis of this approach must address the boiler operating profile with particular attention to the annual average boiler load because the percent boiler load greatly influences the economics. Since there is a high potential for acid corrosion in the economizers at low loads during

the summer, a special by-pass control system to automatically by-pass the economizers at low load may be required. This would add to the cost and complexity of the modification.

The replacement of one of the present water tube boilers with a package fire tube boiler, or the addition of such a boiler for summer operation, is considered to have excellent economic potential for this facility. This modification would provide both summer and winter operation of the boilers at their optimum design conditions. It is presently normal procedure to secure the boiler at night during the summer due to low load. Also, it has been noted that higher than necessary excess air levels are being carried in the summer to artifically load the boiler to maintain sufficient oil pressure at the burner to prevent unstable flame conditions and subsequent boiler trips. These practices reduce boiler efficiency and result in increased boiler maintenance. Another advantage of the package boiler approach is that the packaged fire tube boilers in this size range have a higher thermal efficiency than the water tube boiler. A packaged boiler of about 250 horsepower would generate 30% of the present boiler's rated capacity. With the standard four (4) to one (1) turndown ratio, the boiler would be capable of operating in the load range from 2,150 to 8,625 pounds steam/hour with a boiler efficiency typically of 82% at low load and 83.5% at high load. This boiler size would satisfactorily meet the facilities steam demands for six (6) to seven (7) months of the annual operating period (April to October).

As previously noted, the above alternatives appear to have merit and should be investigated in detail.

6.8 Recommendations

6.8.1 U.S.C.G. Shoreside Boiler Facilities

The following procedure is recommended for U.S.C.G. shoreside boiler installations with either poor boiler efficiency or a flue gas particulate emission problem.

A. Calibrate or obtain instrumentation necessary for efficient

operation. In addition to the normal instrumentation required to safely operate the boiler, an accurate fuel oil meter, feed water meter, flue gas oxygen monitor, opacity monitor, viscometer and stack thermometer are essential for efficient boiler operation.

B. Inspect, repair and replace burner parts, register assemblies and throat brickwork. Check with burner manufacturer to determine if any changes have been made in the original specifications.

C. Trim boiler excess air while operating boiler at steady high load to determine if excess air can be reduced to and run at near design levels.

D. If near design excess air levels cannot be obtained, have burner and combustion control manufacturers representatives come to site for one to two (1-2) days of tuning. The tuning should be done while the boiler is operating at a high, steady load and both representatives should be on site for the same days. First, it is necessary to determine if the burner is capable of operating at design conditions, then the combustion control must be set up to operate as closely as possible to design excess air levels without smoking excessively during load changes.

E. If the burner is not capable of operating at design excess air levels for any reason, such as degraded fuels, conversion of a coal-fired to an oil-fired boiler or poor design, remove emulsifier from U.S.C.G. Academy and install at new site.

F. Determine if emulsifier improves atomization and therefore combustion sufficiently to allow operation at lower excess air level.

6.8.2 U.S.C.G. Academy

The following recommendations pertain specifically to the U.S.C.G. Academy:

* Review present Academy steam consumers characteristics to

determine methods of dampening extreme load fluctuations. These extreme load fluctuations upset the boiler operation and require a considerable cushion of excess air be maintained to prevent excessive smoking during load changes.

* Investigate a more sophisticated combustion control system which would allow maintaining low excess air during load fluctuations.

* Consider the installation of a package boiler sized for summer load. The Bigelow KW 20 boilers are oversized for the summer load and are shut-down at night. Also, it is a common practice to artifically load the boiler during low load periods by increasing the excess air to prevent boiler shut-down due to low load.

* Retain and operate emulsifier at Academy until boiler, as identified in Section 6.8.1, is identified. Also, as fuel quality deteriorates in the future, the emulsifier may significantly improve atomization over the conventional steam atomization.

APPENDIX A

FUEL EMULSIONS LITERATURE

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FUEL EMULSIONS LITERATURE

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APPENDIX B

SAMPLE DATA LOGGER PRINT OUT

SEAWORTHY ENGINE SYSTEMS BOILER EFFICIENCY TEST USCG ACADEMY NEW LONDON

0453	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
100	FEED WT	FEED WT	FEED WT	FUEL	FUEL	FUEL	FUEL	STEAM	STEAM	STEAM	DRAFT	FLU GAS	FLU GAS	AMB AIR	CAL MTR	
200	GPM	PSIA	DEG F	GPM	PSIG	DEG F	SSU	PPH	PSIA	DEG F	IN H20	DEG F	02 PCT	DEG F	DEG F	
11:45:31T	37.95	96.03	216.6F	2.57	31.15	119.6F	289.9	16625	95.29	325.4F	0.47	462.5F	3.24	80.6F	283.7F	
	OPEN +	OPEN +	OPEN +	OPEN +	OPEN +	OPEN +	OPEN +	OPEN +	OPEN +	OPEN +	OPEN +	OPEN +	OPEN +	OPEN +	OPEN +	
12:00:00T	34.93	96.07	217.5F	2.66	30.93	119.0F	294.0	16723	95.56	325.6F	0.50	463.8F	3.37	81.9F	283.8F	
	36.63 +	96.09 +	217.1 +	2.74 +	31.27 +	119.4 +	292.0 +	16896 +	95.41 +	325.5 +	0.50 +	463.4 +	3.24 +	79.7 +	283.7 +	
12:15:00T	35.79	95.96	217.8F	2.79	30.86	118.9F	291.4	16936	95.54	325.6F	0.43	461.8F	3.09	81.5F	283.7F	
	37.65 +	95.99 +	217.7 +	2.73 +	31.14 +	119.3 +	292.0 +	16856 +	95.31 +	325.4 +	0.47 +	461.8 +	3.06 +	80.1 +	283.6 +	
12:30:00T	35.76	96.06	218.1F	2.87	31.43	119.3F	288.5	17747	95.45	325.5F	0.41	459.2F	2.70	77.6F	283.6F	
	37.47 +	96.07 +	218.0 +	2.73 +	31.07 +	119.4 +	289.5 +	16939 +	95.41 +	325.5 +	0.46 +	460.1 +	2.91 +	79.1 +	283.6 +	
12:45:00T	37.62	96.09	217.2F	3.03	31.37	119.5F	292.4	16880	95.27	325.4F	0.49	460.5F	2.86	78.6F	283.5F	
	37.42 +	95.90 +	217.8 +	2.73 +	30.97 +	119.3 +	289.9 +	16928 +	95.21 +	325.4 +	0.46 +	459.9 +	2.94 +	78.9 +	283.6 +	
13:00:00T	38.11	95.89	217.3F	2.67	30.66	119.7F	289.7	16383	95.18	325.3F	0.45	459.8F	3.03	78.4F	283.3F	
	37.18 +	96.08 +	217.1 +	2.72 +	30.95 +	119.3 +	293.9 +	16920 +	95.42 +	325.5 +	0.45 +	460.3 +	2.95 +	79.2 +	283.6 +	
13:15:00T	38.38	95.97	217.3F	2.55	30.69	119.4F	290.4	17193	95.38	325.4F	0.48	460.6F	3.08	80.1F	283.5F	
	37.17 +	96.13 +	217.4 +	2.74 +	30.95 +	119.4 +	290.0 +	16895 +	95.44 +	325.5 +	0.46 +	460.3 +	2.92 +	80.2 +	283.6 +	
13:30:00T	39.43	96.40	217.7F	2.55	30.78	119.4F	291.2	16707	95.62	325.7F	0.41	461.6F	3.08	80.1F	283.5F	
	37.20 +	96.16 +	217.5 +	2.72 +	30.99 +	119.4 +	290.0 +	16897 +	95.47 +	325.5 +	0.46 +	461.0 +	2.93 +	80.4 +	283.5 +	
13:45:00T	37.22	96.43	218.1F	2.63	30.86	119.6F	287.9	16783	95.87	325.7F	0.43	461.5F	2.95	82.6F	283.6F	
	36.99 +	96.48 +	217.9 +	2.72 +	31.06 +	119.5 +	291.8 +	16948 +	95.84 +	325.8 +	0.46 +	461.6 +	2.93 +	80.0 +	283.7 +	
14:00:00T	36.28	96.34	217.9F	2.90	30.89	119.4F	287.2	17176	95.68	325.7F	0.48	462.0F	2.86	81.9F	283.4F	
	37.53 +	96.30 +	218.1 +	2.75 +	31.05 +	119.8 +	284.9 +	16948 +	95.65 +	325.6 +	0.46 +	461.8 +	2.90 +	80.7 +	283.5 +	
14:15:00T	38.04	96.53	218.1F	2.92	31.42	119.4F	287.9	16986	95.68	325.6F	0.48	462.1F	2.69	81.0F	283.4F	
	37.18 +	96.07 +	218.1 +	2.71 +	30.97 +	119.3 +	288.9 +	16955 +	95.43 +	325.5 +	0.46 +	462.1 +	2.96 +	80.5 +	283.4 +	
14:30:00T	38.22	96.37	217.6F	2.70	31.30	119.9F	284.9	16382	95.68	325.5F	0.44	463.2F	2.89	80.3F	283.2F	
	36.98 +	96.15 +	217.9 +	2.72 +	30.97 +	119.5 +	286.6 +	16958 +	95.55 +	325.6 +	0.45 +	462.7 +	3.02 +	80.4 +	283.4 +	
14:45:00T	36.06	96.33	217.6F	2.83	30.70	119.7F	287.0	16467	95.76	325.7F	0.45	464.2F	3.16	81.5F	283.3F	
	37.31 +	96.11 +	217.6 +	2.70 +	30.92 +	119.6 +	286.2 +	16872 +	95.52 +	325.5 +	0.45 +	463.6 +	3.05 +	81.4 +	283.4 +	
15:00:00T	40.08	96.19	217.6F	2.60	30.80	119.2F	291.9	16577	95.54	325.6F	0.44	464.3F	3.09	80.3F	283.4F	
	36.83 +	96.24 +	217.6 +	2.73 +	31.00 +	119.4 +	290.2 +	16950 +	95.69 +	325.7 +	0.45 +	464.1 +	3.02 +	81.7 +	283.4 +	
15:15:00T	37.12	96.04	217.9F	2.54	30.73	119.1F	289.5	16793	95.56	325.5F	0.48	464.9F	3.08	84.2F	283.2F	
	36.73 +	96.13 +	217.6 +	2.71 +	30.99 +	119.3 +	289.2 +	16908 +	95.65 +	325.6 +	0.46 +	464.2 +	2.98 +	81.7 +	283.1 +	
15:30:00T	36.56	96.19	218.9F	2.91	30.81	119.1F	292.5	17021	95.75	325.6F	0.42	465.3F	3.13	83.2F	282.4F	
	37.38 +	96.25 +	218.4 +	2.72 +	31.02 +	119.3 +	291.0 +	16881 +	95.72 +	325.7 +	0.46 +	464.8 +	3.01 +	82.3 +	282.8 +	
15:45:00T	35.66	96.21	218.3F	3.03	31.20	119.0F	292.5	17345	95.75	325.7F	0.40	464.6F	2.67	82.6F	282.1F	
	37.31 +	96.17 +	218.4 +	2.71 +	31.00 +	119.3 +	290.1 +	16886 +	95.67 +	325.6 +	0.46 +	464.9 +	2.97 +	82.1 +	282.1 +	
16:00:00T	37.94	96.50	217.6F	2.76	31.37	119.6F	287.3	16561	95.86	325.7F	0.42	464.8F	2.76	82.2F	281.5F	
	37.55 +	96.13 +	218.0 +	2.70 +	30.94 +	119.1 +	292.3 +	16854 +	95.66 +	325.6 +	0.45 +	465.0 +	2.98 +	81.8 +	281.9 +	

APPENDIX C

SAMPLE FUEL AND WATER ANALYSES

Fuel Engineering Company of New York

Energy and Environmental Services

30 CLAIRMONT AVENUE • THORNWOOD, N.Y. 10594 • (914) 769-7900

Test Report # 316206

Sample Identification U.S.C.G. Academy Blr. #3
Meter reading 250,000

Date Received 1/20/1981

P.O. # P066-01-24

Sampled by: (You) (~~Us~~) Date: 1/10/1981 @0804

CERTIFICATE OF OIL ANALYSIS

Approved by [signature]

Date Mailed 1/23/1981

Seaworthy Engine Systems
36 Main Street
Essex, Connecticut 06426
Attn: Reed Cass

Degrees API @60°F	19.3
Specific Gravity @60°F	0.9383
Flash Point °F	
Bottom Sediment (incl water)	
Sulfur %	0.43
BTU per pound	18945
BTU per gallon	148036
Viscosity @ 122 °F	57.7 SSF
@ 122 °F	120.0 Centistokes
@ 210 °F	17.0 Centistokes
@ °F	
Ash	0.032
Carbon	87.07
Hydrogen	11.67
Sulfur	0.43
Nitrogen	0.30
Oxygen	0.31
Water by Distillation	0.19
Sediment by Extraction	
Pour Point	
Fire Point	
Freezing Point	

CHEMICAL ANALYSIS

Sodium	23 PPM
Vanadium	56 PPM
Potassium	
Iron	
Lead	
Nickel	
Copper	
Magnesium	
Calcium	
Manganese	

Carbon Residue	
Neutralization No.	

Fuel Engineering Company of New York
Energy and Environmental Services
30 CLAIRMONT AVENUE • THORNWOOD, N.Y. 10594 • (914) 769-7900

Test Report # 328615

Date Received 1/18/82

P.O. # P066-01-24

Sample Identification
Oil & Waste Emulsion - Meter= 779,472 Gal.
U.S.C.G. Academy - Boiler #3

Sampled by: (You) (Us) Date: 12/10/81

CERTIFICATE OF OIL ANALYSIS

Approved by F. Wayand

Date Mailed January 25, 1982

Seaworthy Engine Systems, Inc.
36 Main Street
Essex, CT 06426
Attn. Mr. Reed Cass

Degrees API @60°F	17.4
Specific Gravity @60°F	0.9503
Flash Point °F	
Bottom Sediment (incl water) %	
Sulfur %	0.82
BTU per pound	17769
BTU per gallon	140624
Viscosity @ 122 °F	93.7 SFS
@ 122 °F	197.7 CENTISTOKES
@ 150 °F	86.0 CENTISTOKES
@ 210 °F	23.8 CENTISTOKES
Ash	0.04 %
Carbon	81.13 %
Hydrogen	11.40 %
Nitrogen	0.26 %
Oxygen	6.35 %
Sulfur	0.82 %
Water by Distillation	6.0 %
Sediment by Extraction	%
Pour Point	°F
Fire Point	°F
Freezing Point	°F

CHEMICAL ANALYSIS

Sodium	80 PPM
Vanadium	88 PPM
Potassium	
Iron	
Lead	
Nickel	
Copper	
Magnesium	
Calcium	
Manganese	

Carbon Residue

Eastern Analytical Laboratory

251 Main Street - Old Saybrook, Ct. 06475 (203) 388 - 2378

Seaworthy Engine Systems
36 Main Street
Essex, Connecticut

ATTENTION: Reed Cass

Sample # 0132A	City water for water-oil emulsifier	
Date Collected:	12 January 1982	Collected By: Reed Cass
Date Received:	13 January 1982	Time Received: 10:45 AM.

TEST	RESULTS	
POTASSIUM	1.5	mg/l
CALCIUM	9.6	mg/1
SODIUM	11	mg/1
pH	6.65	
CHLORIDES	8	mg/1

no charge for the following tests:

SUSPENDED SOLIDS	13 mg/1
TOTAL DISSOLVED SOLIDS	55 mg/1
TURBIDITY	1.6 units

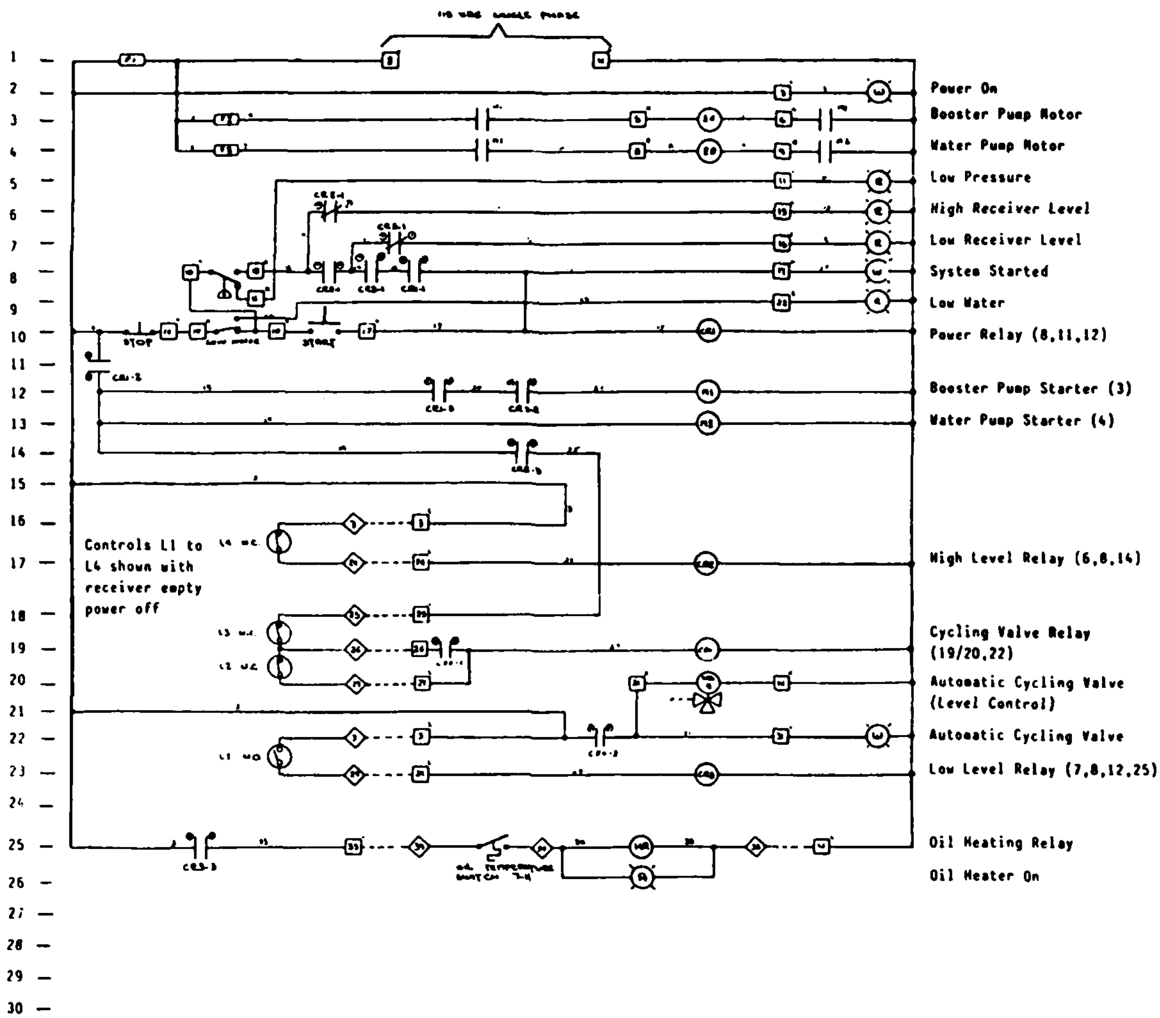
Date of Report: 14 January 1982

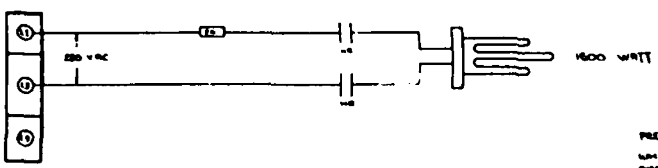
R. M. Kirpas, B.Sc., M.T.
Director

Reg. No. PH0448

APPENDIX D

FOLLAND ST 4 SERIES EMULSION FUEL SYSTEM ELECTRICAL AND MECHANICAL SCHEMATICS





RECEIVER HEATER CONNECTIONS. SEE LINE 25 & 26 ABOVE FOR OTHER ITEMS IN RECEIVER TERMINAL BOX.

PRESSURE SENSING SWITCHES ARE ALL SPST

WHITE INDICATOR LIGHTS INDICATES NORMAL CONDITION
AMBER INDICATOR LIGHTS PROVIDE WARNING ONLY
RED INDICATOR LIGHTS INDICATES EMULSION FUEL SYSTEM SHUTDOWN

---- INDICATES FIELD WIRING

□ INDICATES TERMINAL IN MAIN CONTROL PANEL

◇ INDICATES TERMINAL IN RECEIVER JUNCTION BOX

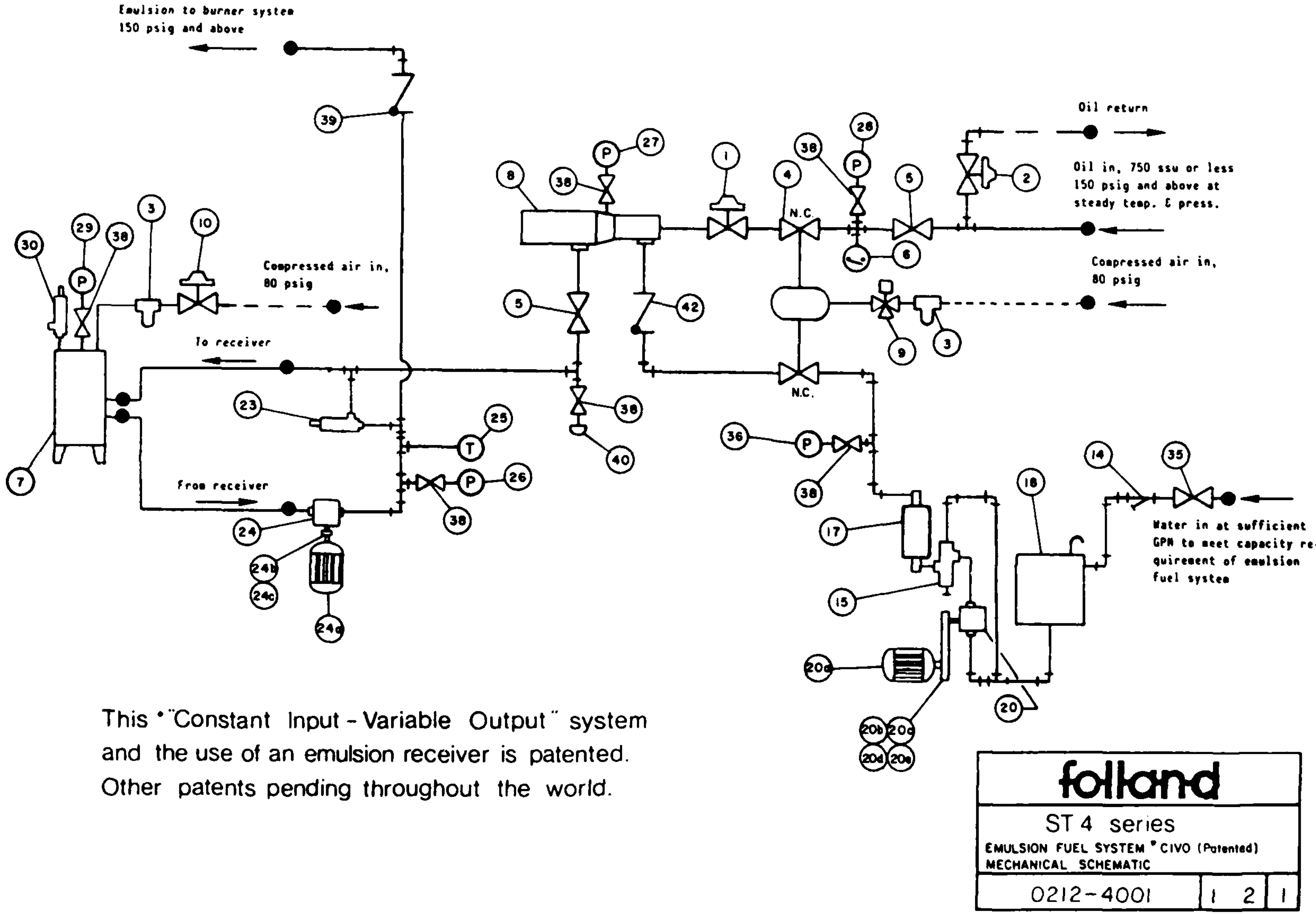
L LEFT SIDE OF PANEL.
R RIGHT SIDE OF PANEL.

CAUTION
THIS UNIT IS FED FROM TWO SEPARATE POWER SOURCES.
BE SURE BOTH SOURCES ARE DISCONNECTED BEFORE SERVICING

RECEIVER TERMINAL BOX FRONT COVER

THIS CONSTANT INPUT-VARIABLE OUTPUT SYSTEM AND THE USE OF AN EMULSION RECEIVER IS PATENTED. OTHER PATENTS PENDING THROUGHOUT THE WORLD.

tolland		
ST 4 SERIES		
115 V.AC 220 V.AC. HEATER		
ELECTRICAL SCHEMATIC		
0212-3001	1 of 1	4



This ® "Constant Input - Variable Output" system and the use of an emulsion receiver is patented. Other patents pending throughout the world.

ITEM	QTY	DESCRIPTION
1	1	Oil pressure regulator
2	1	Oil back pressure regulator
3	2	Air filter
4	1	Automatic cycling valve assembly
5	2	Ball valve, manual
6	1	Low pressure switch
7	1	Receiver assembly
8	1	Barodynamic resonator
9	1	Solenoid valve
10	1	Air pressure regulator
11		
12		
13		
14	1	Water strainer
15	1	Water pressure regulator
16		
17	1	Water flow gauge
18	1	Float tank water supply
19		
20	1	Water pump
20a	1	Motor water pump
20b	1	Sheave motor
20c	1	Sheave pump
20d	1	Guard belt
20e	1	Belt
21		
22		
23	1	Recirculating valve
24	1	Booster pump
24a	1	Motor booster pump
24b	1	Coupling
24c	1	Guard coupling
25	1	Emulsion temperature gauge
26	1	Emulsion pressure gauge
27	1	Injection pressure gauge
28	1	Oil pressure gauge
29	1	Air pressure gauge
30	1	Receiver relief valve
31		
32		
33		
34		
35	1	Ball valve, manual
36	1	Water injection pressure gauge
37		
38	5	Gauge cock
39	1	Ball check valve
40	1	Capped sampling nipple
41		
42	1	Water orifice check valve

folland

ST 4 series

EMULSION FUEL SYSTEM • CIVO (Patented)
MECHANICAL SCHEMATIC

0212-4001 | 2 2 | 1

APPENDIX E

ASME TEST FORMS FOR ABBREVIATED EFFICIENCY TESTS

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series: Preliminary Neat Oil		TEST NO 1	BOILER NO 3	DATE 8/12/80	
OWNER OF PLANT U.S. Coast Guard		LOCATION New London, CT			
TEST CONDUCTED BY Seaworthy Engine Systems		OBJECTIVE OF TEST Measure Efficiency		DURATION 4 HR	
BOILER MAKE & TYPE Bigelow KS 20			RATED CAPACITY 28,500 lbs/hr		
STOKER TYPE & SIZE N/A					
PULVERIZER, TYPE & SIZE N/A			BURNER, SIZE(No) 86-60 (1)		
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A	SIZE AS FIRED N/A	

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	100.7
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	325.7
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	213.8
9	STEAM QUALITY % MOISTURE	%	1.46
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	88
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	84.4
12	TEMPERATURE OF FUEL	F	185.3
13	GAS TEMP. LEAVING (Boiler)	F	348.3
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	298.9
16	ENTHALPY OF (SATURATED STM.	Btu/lb	1174.3
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	181.8
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 - ITEM 17)	Btu/lb	992.5
21	HEAT ABS/LB R.H. STEAM (ITEM 19 - ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8571
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	32.5

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	4970.0
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	353.4
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	6555.0
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	4932.9

FLUE GAS ANAL. (BOILER)(ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	6.5
33	O_2	% VOL	12.6
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	80.9
36	EXCESS AIR	%	138.4

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	85.71
44	HYDROGEN	11.26
45	OXYGEN	2.22
46	NITROGEN	0.37
47	SULPHUR	0.41
40	ASH	0.028
37	MOISTURE	1.6
	TOTAL	

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9580
53	VISCOSITY AT SSU* BURNER	160
44	TOTAL HYDROGEN % wt	11.26
41	Btu per lb	18548

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	75.2

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	2056.6	11.1
66	HEAT LOSS DUE TO MOISTURE IN FUEL	18.6	0.1
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1181.0	6.4
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	5.0
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		25.5
72	EFFICIENCY = (100 - Item 71)		74.5

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series: Preliminary Neat Oil	TEST NO 2	BOILER NO. 3	DATE 8/12/80
OWNER OF PLANT U.S. Coast Guard	LOCATION New London, CT		
TEST CONDUCTED BY Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 4 HR	
BOILER MAKE & TYPE Bigelow KS 20	RATED CAPACITY 28,500 lbs/hr		
STOKER TYPE & SIZE N/A			
PULVERIZER, TYPE & SIZE N/A	BURNER, SIZE(No) 86-60 (2)		
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A · SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	100.1
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	325.2
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	209.4
9	STEAM QUALITY % MOISTURE	%	1.50
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	93
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	91.6
12	TEMPERATURE OF FUEL	F	185.4
13	GAS TEMP. LEAVING (Boiler)	F	390.1
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	298.4
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1173.9
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	177.4
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	996.5
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8571
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	23.4

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	8933.1
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	623.2
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	11558.9
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	8901.5

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	9.1
33	O_2	% VOL	9.3
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	81.6
36	EXCESS AIR	%	73.8

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9580
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	160
40	ASH	N/A	44	TOTAL HYDROGEN % wt	11.26
	TOTAL		41	Btu per lb	18548
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP ASTM METHOD	N/A		GAS	% VOL

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS				
			54	CO	N/A
43	CARBON	85.71	55	CH_4 METHANE	N/A
44	HYDROGEN	11.26	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	2.22	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.37	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.41	59	H_2S	N/A
40	ASH	0.028	60	CO_2	N/A
37	MOISTURE	1.6	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	

	COAL PULVERIZATION				
				TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M	N/A	41	Btu PER LB	N/A
64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29			77.0

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1678.3	9.0
66	HEAT LOSS DUE TO MOISTURE IN FUEL	18.8	0.1
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1193.5	6.4
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	2.8
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		21.4
72	EFFICIENCY = (100 – Item 71)		78.6

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series: Preliminary Neat Oil	TEST NO 3	BOILER NO. 3	DATE 8/13/80
OWNER OF PLANT U.S. Coast Guard	LOCATION New London, CT		
TEST CONDUCTED BY Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 4 HR	
BOILER MAKE & TYPE Bigelow KS 20	RATED CAPACITY 28,500 lbs/hr		
STOKER TYPE & SIZE N/A			
PULVERIZER, TYPE & SIZE N/A	BURNER, SIZE(No) 102-73 (2)		
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A / SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	102.6
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	326.8
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R. H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	218.5
9	STEAM QUALITY % MOISTURE	%	1.50
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	87
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature)	F	84.6
12	TEMPERATURE OF FUEL	F	184.1
13	GAS TEMP. LEAVING (Boiler)	F	413.0
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	300.3
16	ENTHALPY OF (SATURATED STM.	Btu/lb	1174.3
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	186.5
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	987.8
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8571
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	20.6

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	11829.9
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	798.3
29	TOTAL HEAT INPUT (Item 28 x Item 41) / 1000	kB/hr	14806.8
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	11686.0

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	10.4
33	O_2	% VOL	7.6
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.0
36	EXCESS AIR	%	52.8

FUEL DATA

No.	COAL AS FIRED PROX. ANALYSIS	% wt	No.	OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9580
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	162
40	ASH	N/A	44	TOTAL HYDROGEN % wt	11.26
	TOTAL		41	Btu per lb	18548
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP.* ASTM METHOD	N/A		GAS	% VOL
	COAL OR OIL AS FIRED ULTIMATE ANALYSIS		54	CO	N/A
43	CARBON	85.71	55	CH_4 METHANE	N/A
44	HYDROGEN	11.26	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	2.22	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.37	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.41	59	H_2S	N/A
40	ASH	0.028	60	CO_2	N/A
37	MOISTURE	1.6	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	
	COAL PULVERIZATION			TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	78.9

No.	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1623.4	8.8
66	HEAT LOSS DUE TO MOISTURE IN FUEL	19.1	0.1
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1211.4	6.5
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	2.2
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		20.6
72	EFFICIENCY = (100 – Item 71)		79.4

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Preliminary Neat Oil	TEST NO 5	BOILER NO. 3	DATE 8/14/80	
OWNER OF PLANT	U.S. Coast Guard	LOCATION New London, CT			
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 4 HR		
BOILER MAKE & TYPE	Bigelow KS 20	RATED CAPACITY 28,500 lbs/hr			
STOKER TYPE & SIZE	N/A				
PULVERIZER, TYPE & SIZE	N/A	BURNER, SIZE(No) 109-78 (2)			
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A	SIZE AS FIRED N/A	

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	101.8
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	325.7
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	214.8
9	STEAM QUALITY % MOISTURE	%	2.39
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	83
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	83.0
12	TEMPERATURE OF FUEL	F	177.2
13	GAS TEMP. LEAVING (Boiler)	F	486.7
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	299.7
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1166.3
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	182.8
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 - ITEM 17)	Btu/lb	983.5
21	HEAT ABS/LB R.H. STEAM (ITEM 19 - ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8571
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	20.6

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	17959.3
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1221.2
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	22650.6
30	HEAT OUTPUT IN BLOW DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	17662.7

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	10.4
33	O_2	% VOL	7.6
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.0
36	EXCESS AIR	%	52.8

FUEL DATA

No.	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

No.	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9580
53	VISCOSITY AT SSU* BURNER	167
44	TOTAL HYDROGEN % wt	11.26
41	Btu per lb	18548

No.	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	85.71
44	HYDROGEN	11.26
45	OXYGEN	2.22
46	NITROGEN	0.37
47	SULPHUR	0.41
40	ASH	0.028
37	MOISTURE	1.6
	TOTAL	

No.	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

No.	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

No.		
64	INPUT-OUTPUT EFFICIENCY OF UNIT % (ITEM 31 × 100 / ITEM 29)	78.0

No.	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1995.7	10.8
66	HEAT LOSS DUE TO MOISTURE IN FUEL	19.7	0.1
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1247.9	6.7
68	HEAT LOSS DUE TO COMBUST IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	1.4
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		22.0
72	EFFICIENCY (100 - Item 71)		78.0

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series: Preliminary Neat Oil	TEST NO 6	BOILER NO 3	DATE 8/14/80
OWNER OF PLANT U.S. Coast Guard	LOCATION New London, CT		
TEST CONDUCTED BY Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 3 HR	
BOILER MAKE & TYPE Bigelow KS 20	RATED CAPACITY 28,500 lbs/hr		
STOKER TYPE & SIZE N/A			
PULVERIZER, TYPE & SIZE N/A	BURNER, SIZE (No) 109-78 (2)		
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A — SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	101.7
2	STEAM PRESSURE AT S.H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R.H. INLET	psia	N/A
4	STEAM PRESSURE AT R.H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	325.0
6	STEAM TEMPERATURE AT R.H. INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	216.8
9	STEAM QUALITY % MOISTURE	%	1.48
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	88
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	83.5
12	TEMPERATURE OF FUEL	F	185.8
13	GAS TEMP. LEAVING (Boiler)	F	547.3
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	299.7
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1174.3
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	184.8
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R.H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	989.5
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8571
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	20.6

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	22777.6
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1638.1
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	30382.7
30	HEAT OUTPUT IN BLOW DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	22539.2

FLUE GAS ANAL. (BOILER) (ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	10.4
33	O_2	% VOL	7.7
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	81.9
36	EXCESS AIR	%	53.9

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP. ASTM METHOD	N/A

	OIL	
51	FLASH POINT F*	No Data
52	Sp Gravity	0.9580
53	VISCOSITY AT SSU* BURNER	158
44	TOTAL HYDROGEN % wt	11.26
41	Btu per lb	18548

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	85.71
44	HYDROGEN	11.26
45	OXYGEN	2.22
46	NITROGEN	0.37
47	SULPHUR	0.41
40	ASH	0.028
37	MOISTURE	1.6
	TOTAL	

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	74.2

	HEAT LOSS EFFICIENCY	Btu/lb A.F. FUEL	% of A.F. FUEL
65	HEAT LOSS DUE TO DRY GAS	2293.1	12.4
66	HEAT LOSS DUE TO MOISTURE IN FUEL	20.1	0.1
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1276.1	6.9
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	1.1
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		23.5
72	EFFICIENCY = (100 – Item 71)		76.5

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series: Preliminary Neat Oil	TEST NO 7	BOILER NO. 3	DATE 8/15/80
OWNER OF PLANT U.S. Coast Guard	LOCATION New London, CT		
TEST CONDUCTED BY Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 2 HR	
BOILER MAKE & TYPE Bigelow KS 20	RATED CAPACITY 28,500 lbs/hr		
STOKER TYPE & SIZE N/A			
PULVERIZER, TYPE & SIZE N/A	BURNER, SIZE(No) 125-89 (2)		
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A, SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	102.1
2	STEAM PRESSURE AT S.H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R.H. INLET	psia	N/A
4	STEAM PRESSURE AT R.H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	324.8
6	STEAM TEMPERATURE AT R.H. INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	218.6
9	STEAM QUALITY % MOISTURE	%	1.59
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	87
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	82.6
12	TEMPERATURE OF FUEL	F	157.5
13	GAS TEMP. LEAVING (Boiler)	F	534.4
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	300.0
16	ENTHALPY OF (SATURATED STM.	Btu/lb	1173.4
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	186.6
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R.H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	986.8
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8571
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	16.5

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	25190.1
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1767.9
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	32790.5
30	HEAT OUTPUT IN BLOW DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	24857.4

FLUE GAS ANAL. (BOILER)(ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	13.1
33	O_2	% VOL	4.4
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.5
36	EXCESS AIR	%	24.8

FUEL DATA

No.	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP ASTM METHOD	N/A

No.	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9580
53	VISCOSITY AT SSU* BURNER	294
44	TOTAL HYDROGEN % wt	11.26
41	Btu per lb	18548

No.	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	85.71
44	HYDROGEN	11.26
45	OXYGEN	2.22
46	NITROGEN	0.37
47	SULPHUR	0.41
40	ASH	0.028
37	MOISTURE	1.6
	TOTAL	

No.	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

No.	COAL PULVERIZATION	
48	GRINDABILITY INDEX	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

No.		
64	INPUT-OUTPUT EFFICIENCY OF UNIT % (ITEM 31 × 100 / ITEM 29)	75.8

No.	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1791.4	9.7
66	HEAT LOSS DUE TO MOISTURE IN FUEL	20.1	0.1
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1270.9	6.8
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	1.0
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		20.7
72	EFFICIENCY = (100 – Item 71)		79.3

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series: Preliminary Neat Oil	TEST NO 8	BOILER NO. 3	DATE 8/15/80
OWNER OF PLANT U.S. Coast Guard	LOCATION New London, CT		
TEST CONDUCTED BY Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 2 HR	
BOILER MAKE & TYPE Bigelow KS 20	RATED CAPACITY 28,500 lbs/hr		
STOKER TYPE & SIZE N/A			
PULVERIZER, TYPE & SIZE N/A	BURNER, SIZE(No) 125-89 (2)		
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A — SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	101.7
2	STEAM PRESSURE AT S.H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R.H. INLET	psia	N/A
4	STEAM PRESSURE AT R.H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	324.2
6	STEAM TEMPERATURE AT R.H. INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	183.5
9	STEAM QUALITY % MOISTURE	%	1.88
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	90
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	86.1
12	TEMPERATURE OF FUEL	F	162.2
13	GAS TEMP. LEAVING (Boiler)	F	571.2
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	299.7
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1170.7
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	151.5
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R.H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	1019.2
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8571
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	16.8

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	28253.5
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	2060.8
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	38224.6
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	28797.2

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	12.9
33	O_2	% VOL	4.2
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.9
36	EXCESS AIR	%	23.2

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9580
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	267
40	ASH	N/A	44	TOTAL HYDROGEN % wt	11.26
	TOTAL		41	Btu per lb	18548
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP.* ASTM METHOD	N/A		GAS	% VOL
	COAL OR OIL AS FIRED ULTIMATE ANALYSIS		54	CO	N/A
43	CARBON	85.71	55	CH_4 METHANE	N/A
44	HYDROGEN	11.26	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	2.22	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.37	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.41	59	H_2S	N/A
40	ASH	0.028	60	CO_2	N/A
37	MOISTURE	1.6	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	
	COAL PULVERIZATION			TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	75.3

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1950.7	10.5
66	HEAT LOSS DUE TO MOISTURE IN FUEL	20.3	0.1
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1284.8	6.9
68	HEAT LOSS DUE TO COMBUST IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	0.9
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		21.4
72	EFFICIENCY = (100 – Item 71)		78.6

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series: Pre Long Term Neat Oil	TEST NO 1	BOILER NO. 3	DATE 9/9/80
OWNER OF PLANT U.S. Coast Guard	LOCATION New London, CT		
TEST CONDUCTED BY Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 4 HR	
BOILER MAKE & TYPE Bigelow KS 20	RATED CAPACITY 28,500 lbs/hr		
STOKER TYPE & SIZE N/A			
PULVERIZER, TYPE & SIZE N/A	BURNER, SIZE (No) 116-82 (2)		
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A · SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	102.8
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	328.7
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	217.1
9	STEAM QUALITY % MOISTURE	%	0.63
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	86
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	79.1
12	TEMPERATURE OF FUEL	F	168.8
13	GAS TEMP. LEAVING (Boiler)	F	380.8
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	300.5
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1182.0
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	185.1
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	996.9
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8641
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	18.5

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	10493.7
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	711.4
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	13148.3
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	10461.4

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	11.8
33	O_2	% VOL	5.5
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.7
36	EXCESS AIR	%	32.5

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9567
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	208
40	ASH	N/A	44	TOTAL HYDROGEN % wt	11.31
	TOTAL		41	Btu per lb	18481
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP.* ASTM METHOD	N/A		GAS	% VOL
	COAL OR OIL AS FIRED ULTIMATE ANALYSIS		54	CO	N/A
43	CARBON	86.41	55	CH_4 METHANE	N/A
44	HYDROGEN	11.31	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	0.25	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.35	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.45	59	H_2S	N/A
40	ASH	0.031	60	CO_2	N/A
37	MOISTURE	1.2	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	
	COAL PULVERIZATION			TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	79.6

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1337.1	7.2
66	HEAT LOSS DUE TO MOISTURE IN FUEL	14.2	0.1
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1207.1	6.5
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	2.4
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		19.2
72	EFFICIENCY = (100 – Item 71)		80.8

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Pre Long Term Neat Oil	TEST NO	2	BOILER NO. 3	DATE 9/10/80
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT		
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST	Measure Efficiency	DURATION	5.5 HR
BOILER MAKE & TYPE	Bigelow KS 20	RATED CAPACITY	28,500 lbs/hr		
STOKER TYPE & SIZE	N/A				
PULVERIZER, TYPE & SIZE	N/A	BURNER, SIZE(No)	116-82 (2)		
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A	SIZE AS FIRED	N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	101.4
2	STEAM PRESSURE AT S.H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R.H. INLET	psia	N/A
4	STEAM PRESSURE AT R.H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	328.0
6	STEAM TEMPERATURE AT R.H. INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	218.4
9	STEAM QUALITY % MOISTURE	%	0.45
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	85
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	80.7
12	TEMPERATURE OF FUEL	F	168.2
13	GAS TEMP. LEAVING (Boiler)	F	383.9
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	299.4
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1183.4
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	186.4
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R.H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	997.0
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8641
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	17.4

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	10088.9
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	692.8
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	12804.1
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	10058.9

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	12.5
33	O_2	% VOL	4.5
34	CO	% VOL	0.00
35	N_2 (BY DIFFERENCE)	% VOL	83.0
36	EXCESS AIR	%	25.3

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP ASTM METHOD	N/A

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9567
53	VISCOSITY AT SSU* BURNER	210
44	TOTAL HYDROGEN % wt	11.31
41	Btu per lb	18481

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	86.41
44	HYDROGEN	11.31
45	OXYGEN	0.25
46	NITROGEN	0.35
47	SULPHUR	0.45
40	ASH	0.031
37	MOISTURE	1.2
	TOTAL	

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	78.6

	HEAT LOSS EFFICIENCY	Btu/lb A.F. FUEL	% of A.F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1267.6	6.9
66	HEAT LOSS DUE TO MOISTURE IN FUEL	14.2	0.1
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1206.9	6.5
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	2.5
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		19.0
72	EFFICIENCY = (100 – Item 71)		81.0

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series: Pre Long Term Neat Oil	TEST NO 3	BOILER NO. 3	DATE 9/10/80
OWNER OF PLANT U.S. Coast Guard	LOCATION New London, CT		
TEST CONDUCTED BY Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 4 HR	
BOILER MAKE & TYPE Bigelow KS 20	RATED CAPACITY 28,500 lbs/hr		
STOKER TYPE & SIZE N/A			
PULVERIZER, TYPE & SIZE N/A	BURNER, SIZE (No) 116-82 (2)		
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A; SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	101.2
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	327.8
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	218.7
9	STEAM QUALITY % MOISTURE	%	0.39
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	88
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	81.3
12	TEMPERATURE OF FUEL	F	165.9
13	GAS TEMP. LEAVING (Boiler)	F	353.5
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	299.3
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1183.9
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	186.7
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	997.2
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8641
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	18.8

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	8940.0
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	599.8
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	11085.1
30	HEAT OUTPUT IN BLOW DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	8914.9

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	11.5
33	O_2	% VOL	5.3
34	CO	% VOL	0.00
35	N_2 (BY DIFFERENCE)	% VOL	83.2
36	EXCESS AIR	%	31.2

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9567
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU BURNER	217
40	ASH	N/A	44	TOTAL HYDROGEN % wt	11.31
	TOTAL		41	Btu per lb	18481
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP.* ASTM METHOD	N/A		GAS	% VOL
	COAL OR OIL AS FIRED ULTIMATE ANALYSIS		54	CO	N/A
43	CARBON	86.41	55	CH_4 METHANE	N/A
44	HYDROGEN	11.31	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	0.25	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.35	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.45	59	H_2S	N/A
40	ASH	0.031	60	CO_2	N/A
37	MOISTURE	1.2	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	
	COAL PULVERIZATION			TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	80.4

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1231.7	6.7
66	HEAT LOSS DUE TO MOISTURE IN FUEL	14.0	0.1
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1191.8	6.4
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	2.8
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		19.0
72	EFFICIENCY (100 – Item 71)		81.0

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Pre Long Term Neat Oil
TEST NO	4
BOILER NO.	3
DATE	9/11/80
OWNER OF PLANT	U.S. Coast Guard
LOCATION	New London, CT
TEST CONDUCTED BY	Seaworthy Engine Systems
OBJECTIVE OF TEST	Measure Efficiency
DURATION	4 HR
BOILER MAKE & TYPE	Bigelow KS 20
RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A
PULVERIZER, TYPE & SIZE	N/A
BURNER, SIZE(No)	116-82 (2)
FUEL USED	Oil
MINE	N/A
COUNTY	N/A
STATE	N/A
SIZE AS FIRED	N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	100.5
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	327.2
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	218.3
9	STEAM QUALITY % MOISTURE	%	0.35
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	87
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	81.5
12	TEMPERATURE OF FUEL	F	164.2
13	GAS TEMP. LEAVING (Boiler)	F	352.9
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	298.8
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1184.1
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	186.3
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	997.8
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8641
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	18.7

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	9350.2
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	628.1
29	TOTAL HEAT INPUT (Item 28 x Item 41) / 1000	kB/hr	11608.3
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 x Item 20) + (Item 27 x Item 21) + Item 30 / 1000	kB/hr	9329.8

FLUE GAS ANAL. (BOILER)(ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	11.6
33	O_2	% VOL	5.1
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	83.3
36	EXCESS AIR	%	29.5

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	86.41
44	HYDROGEN	11.31
45	OXYGEN	0.25
46	NITROGEN	0.35
47	SULPHUR	0.45
40	ASH	0.031
37	MOISTURE	1.2
	TOTAL	

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9567
53	VISCOSITY AT SSU* BURNER	244
44	TOTAL HYDROGEN % wt	11.31
41	Btu per lb	18481

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	80.4

HEAT LOSS EFFICIENCY

		Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1216.8	6.6
66	HEAT LOSS DUE TO MOISTURE IN FUEL	14.0	0.1
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1191.4	6.4
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	2.7
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		18.8
72	EFFICIENCY = (100 – Item 71)		81.2

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Pre Long Term Neat Oil	TEST NO	5	BOILER NO.	3	DATE	9/12/80
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT				
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST	Measure Efficiency	DURATION	4 HR		
BOILER MAKE & TYPE	Bigelow KS 20	RATED CAPACITY	28,500 lbs/hr				
STOKER TYPE & SIZE	N/A						
PULVERIZER, TYPE & SIZE	N/A	BURNER, SIZE (No)	116-82 (2)				
FUEL USED	Oil	MINE	N/A	COUNTY	N/A	STATE	N/A
SIZE AS FIRED	N/A						

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	102.9
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	327.3
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	218.8
9	STEAM QUALITY % MOISTURE	%	0.38
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	82
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	82.0
12	TEMPERATURE OF FUEL	F	162.9
13	GAS TEMP. LEAVING (Boiler)	F	549.5
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	300.6
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1184.3
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	186.8
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 - ITEM 17)	Btu/lb	997.5
21	HEAT ABS/LB R.H. STEAM (ITEM 19 - ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8641
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	16.9

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	27249.6
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1915.6
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	35401.6
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	27181.8

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	12.9
33	O_2	% VOL	4.3
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.8
36	EXCESS AIR	%	24.0

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	86.41
44	HYDROGEN	11.31
45	OXYGEN	0.25
46	NITROGEN	0.35
47	SULPHUR	0.45
40	ASH	0.031
37	MOISTURE	1.2
	TOTAL	

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9567
53	VISCOSITY AT SSU* BURNER	251
44	TOTAL HYDROGEN % wt	11.31
41	Btu per lb	18481

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT % (ITEM 31 × 100 / ITEM 29)	76.8

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1896.0	10.2
66	HEAT LOSS DUE TO MOISTURE IN FUEL	15.1	0.1
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1284.3	6.9
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	1.0
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		21.2
72	EFFICIENCY = (100 - Item 71)		78.8

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Pre Long Term Neat Oil	TEST NO	6	BOILER NO. 3	DATE 9/12/80
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT		
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST	Measure Efficiency	DURATION	4 HR
BOILER MAKE & TYPE	Bigelow KS 20			RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A				
PULVERIZER, TYPE & SIZE	N/A			BURNER, SIZE(No)	116-82 (2)
FUEL USED Oil	MINE N/A	COUNTY	N/A	STATE N/A	SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	103.3
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	327.4
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	219.3
9	STEAM QUALITY % MOISTURE	%	0.35
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	84
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	78.9
12	TEMPERATURE OF FUEL	F	163.7
13	GAS TEMP. LEAVING (Boiler)	F	550.5
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	300.8
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1184.6
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	187.3
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	997.3
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8641
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	16.1

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	27860.3
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1922.4
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	35528.2
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	27786.1

FLUE GAS ANAL. (BOILER)(ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	13.6
33	O_2	% VOL	3.6
34	CO	% VOL	0.00
35	N_2 (BY DIFFERENCE)	% VOL	82.8
36	EXCESS AIR	%	19.3

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP. ASTM METHOD	N/A

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	86.41
44	HYDROGEN	11.31
45	OXYGEN	0.25
46	NITROGEN	0.35
47	SULPHUR	0.45
40	ASH	0.031
37	MOISTURE	1.2
	TOTAL	

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9567
53	VISCOSITY AT SSU* BURNER	256
44	TOTAL HYDROGEN % wt	11.31
41	Btu per lb	18481

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT % — ITEM 31 × 100 / ITEM 29	78.2

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1820.6	9.8
66	HEAT LOSS DUE TO MOISTURE IN FUEL	15.2	0.1
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1288.0	7.0
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	0.9
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		20.8
72	EFFICIENCY = (100 – Item 71)		79.2

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series: Pre Long Term Neat Oil	TEST NO 7	BOILER NO 3	DATE 9/15/80
OWNER OF PLANT U.S. Coast Guard	LOCATION New London, CT		
TEST CONDUCTED BY Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 4 HR	
BOILER MAKE & TYPE Bigelow KS 20	RATED CAPACITY 28,500 lbs/hr		
STOKER TYPE & SIZE N/A			
PULVERIZER, TYPE & SIZE N/A	BURNER, SIZE(No) 116-82 (2)		
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	101.1
2	STEAM PRESSURE AT S.H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R.H. INLET	psia	N/A
4	STEAM PRESSURE AT R.H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	326.3
6	STEAM TEMPERATURE AT R.H. INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	219.2
9	STEAM QUALITY % MOISTURE	%	0.35
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	79
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	79.0
12	TEMPERATURE OF FUEL	F	160.3
13	GAS TEMP. LEAVING (Boiler)	F	552.3
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	299.2
16	ENTHALPY OF (SATURATED STM.	Btu/lb	1184.2
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	187.2
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R.H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	997.0
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8641
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	16.2

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	27004.2
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1901.4
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	35139.8
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	26923.7

FLUE GAS ANAL. (BOILER)(ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	13.5
33	O_2	% VOL	3.4
34	CO	% VOL	0.00
35	N_2 (BY DIFFERENCE)	% VOL	83.1
36	EXCESS AIR	%	18.0

FUEL DATA

No.	COAL AS FIRED PROX. ANALYSIS	% wt	No.	OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9567
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	277
40	ASH	N/A	44	TOTAL HYDROGEN % wt	11.31
	TOTAL		41	Btu per lb	18481
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP ASTM METHOD	N/A		GAS	% VOL

No.	COAL OR OIL AS FIRED ULTIMATE ANALYSIS		No.	GAS	% VOL
			54	CO	N/A
43	CARBON	86.41	55	CH_4 METHANE	N/A
44	HYDROGEN	11.31	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	0.25	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.35	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.45	59	H_2S	N/A
40	ASH	0.031	60	CO_2	N/A
37	MOISTURE	1.2	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	
	COAL PULVERIZATION			TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT % = ITEM 31 × 100 / ITEM 29		76.6

No.	HEAT LOSS EFFICIENCY	Btu/lb A.F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1839.2	10.0
66	HEAT LOSS DUE TO MOISTURE IN FUEL	15.2	0.1
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1288.7	7.0
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	0.9
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		21.0
72	EFFICIENCY = (100 – Item 71)		79.0

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

UMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Pre Long Term Neat Oil	TEST NO 8	BOILER NO. 3	DATE 9/15/80	
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT		
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST	Measure Efficiency	DURATION	4 HR
BOILER MAKE & TYPE	Bigelow KS 20			RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A				
PULVERIZER, TYPE & SIZE	N/A			BURNER, SIZE(No)	116-82(2)
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A	SIZE AS FIRED	N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	101.1
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	326.8
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	219.6
9	STEAM QUALITY % MOISTURE	%	0.35
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	75
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	76.6
12	TEMPERATURE OF FUEL	F	167.1
13	GAS TEMP. LEAVING (Boiler)	F	505.3
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	299.2
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1184.2
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	187.6
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 - ITEM 17)	Btu/lb	996.6
21	HEAT ABS/LB R.H. STEAM (ITEM 19 - ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8641
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	16.4

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	23213.2
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1589.2
29	TOTAL HEAT INPUT (Item 28 x Item 41) / 1000	kB/hr	29370.7
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	23134.7

FLUE GAS ANAL. (BOILER)(ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	13.3
33	O_2	% VOL	4.2
34	CO	% VOL	0.00
35	N_2 (BY DIFFERENCE)	% VOL	82.5
36	EXCESS AIR	%	23.4

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9567
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	238
40	ASH	N/A	44	TOTAL HYDROGEN % wt	11.31
	TOTAL		41	Btu per lb	18481
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP.* ASTM METHOD	N/A		GAS	% VOL
	COAL OR OIL AS FIRED ULTIMATE ANALYSIS		54	CO	N/A
43	CARBON	86.41	55	CH_4 METHANE	N/A
44	HYDROGEN	11.31	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	0.25	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.35	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.45	59	H_2S	N/A
40	ASH	0.031	60	CO_2	N/A
37	MOISTURE	1.2	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	
	COAL PULVERIZATION			TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	78.8

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1691.0	9.1
66	HEAT LOSS DUE TO MOISTURE IN FUEL	15.0	0.1
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1268.8	6.9
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	1.1
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		20.2
72	EFFICIENCY = (100 - Item 71)		79.8

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a(1964)

Test Series: Pre Long Term Neat Oil	TEST NO 9	BOILER NO. 3	DATE 9/16/80
OWNER OF PLANT U.S. Coast Guard	LOCATION New London, CT		
TEST CONDUCTED BY Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 4 HR	
BOILER MAKE & TYPE Bigelow KS 20	RATED CAPACITY 28,500 lbs/hr		
STOKER TYPE & SIZE N/A			
PULVERIZER, TYPE & SIZE N/A	BURNER, SIZE(No) 116-82 (2)		
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A; SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	100.0
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	326.6
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	220.4
9	STEAM QUALITY % MOISTURE	%	0.49
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	79
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	74.3
12	TEMPERATURE OF FUEL	F	166.4
13	GAS TEMP. LEAVING (Boiler)	F	437.1
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	298.4
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1182.8
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	188.4
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	994.4
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8641
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	17.2

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	15638.7
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1055.8
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	19512.9
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	15550.7

FLUE GAS ANAL. (BOILER)(ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	12.7
33	O_2	% VOL	4.5
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.8
36	EXCESS AIR	%	25.4

FUEL DATA

No.	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

No.	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	% wt
43	CARBON	86.41
44	HYDROGEN	11.31
45	OXYGEN	0.25
46	NITROGEN	0.35
47	SULPHUR	0.45
40	ASH	0.031
37	MOISTURE	1.2
	TOTAL	

No.	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9567
53	VISCOSITY AT SSU* BURNER	250
44	TOTAL HYDROGEN % wt	11.31
41	Btu per lb	18481

No.	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

No.	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT % (ITEM 31 × 100 / ITEM 29)	79.7

No.	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1493.3	8.1
66	HEAT LOSS DUE TO MOISTURE IN FUEL	14.6	0.1
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1238.7	6.7
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	1.6
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		19.5
72	EFFICIENCY = (100 – Item 71)		80.5

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Pre Long Term Neat Oil	TEST NO 10	BOILER NO. 3 DATE 9/16/80
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 4 HR
BOILER MAKE & TYPE	Bigelow KS 20	RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A		
PULVERIZER, TYPE & SIZE	N/A	BURNER, SIZE(No)	116-82 (2)
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	101.1
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	327.8
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R. H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	220.6
9	STEAM QUALITY % MOISTURE	%	0.57
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	74
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	73.0
12	TEMPERATURE OF FUEL	F	158.7
13	GAS TEMP. LEAVING (Boiler)	F	417.3
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	299.2
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1182.3
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	188.6
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	993.7
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8641
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	16.8

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	13328.5
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	921.1
29	TOTAL HEAT INPUT (Item 28 x Item 41) / 1000	kB/hr	17022.9
30	HEAT OUTPUT IN BLOW DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	132440

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	13.0
33	O_2	% VOL	4.1
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.9
36	EXCESS AIR	%	22.6

FUEL DATA

No.	COAL AS FIRED PROX. ANALYSIS	% wt	No.	OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9567
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	291
40	ASH	N/A	44	TOTAL HYDROGEN % wt	11.31
	TOTAL		41	Btu per lb	18481
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP.* ASTM METHOD	N/A		GAS	% VOL

No.	COAL OR OIL AS FIRED ULTIMATE ANALYSIS		No.	GAS	% VOL
			54	CO	N/A
43	CARBON	86.41	55	CH_4 METHANE	N/A
44	HYDROGEN	11.31	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	0.25	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.35	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.45	59	H_2S	N/A
40	ASH	0.031	60	CO_2	N/A
37	MOISTURE	1.2	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	

No.	COAL PULVERIZATION		No.		
				TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A
64	INPUT-OUTPUT EFFICIENCY OF UNIT % (ITEM 31 × 100 / ITEM 29)	77.8			

No.	HEAT LOSS EFFICIENCY	Btu/lb A.F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1385.9	7.5
66	HEAT LOSS DUE TO MOISTURE IN FUEL	14.5	0.1
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1230.6	6.7
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	----	----
69	HEAT LOSS DUE TO RADIATION	----	1.9
70	UNMEASURED LOSSES	----	3.0
71	TOTAL		19.2
72	EFFICIENCY = (100 – Item 71)		80.8

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Pre Long Term Neat Oil	TEST NO 11	BOILER NO. 3	DATE 9/17/80	
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT		
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST	Measure Efficiency	DURATION	4 HR
BOILER MAKE & TYPE	Bigelow KS 20	RATED CAPACITY	28,500 lbs/hr		
STOKER TYPE & SIZE	N/A				
PULVERIZER, TYPE & SIZE	N/A	BURNER, SIZE(No)	116-82 (2)		
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A	SIZE AS FIRED N/A	

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	99.1
2	STEAM PRESSURE AT S.H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R.H. INLET	psia	N/A
4	STEAM PRESSURE AT R.H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	325.5
6	STEAM TEMPERATURE AT R.H. INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	218.4
9	STEAM QUALITY % MOISTURE	%	0.36
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	75
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	72.5
12	TEMPERATURE OF FUEL	F	158.3
13	GAS TEMP. LEAVING (Boiler)	F	471.0
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	297.7
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1183.8
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	186.4
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R.H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 - ITEM 17)	Btu/lb	997.4
21	HEAT ABS/LB R.H. STEAM (ITEM 19 - ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8641
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	16.5

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	17722.6
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1253.8
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	23172.1
30	HEAT OUTPUT IN BLOW DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	176765

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	13.2
33	O_2	% VOL	3.8
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	83.0
36	EXCESS AIR	%	20.6

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9567
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	307
40	ASH	N/A	44	TOTAL HYDROGEN % wt	11.31
	TOTAL		41	Btu per lb	18481
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP ASTM METHOD	N/A		GAS	% VOL
	COAL OR OIL AS FIRED ULTIMATE ANALYSIS		54	CO	N/A
43	CARBON	86.41	55	CH_4 METHANE	N/A
44	HYDROGEN	11.31	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	0.25	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.35	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.45	59	H_2S	N/A
40	ASH	0.031	60	CO_2	N/A
37	MOISTURE	1.2	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	
	COAL PULVERIZATION			TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29 = 76.3

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1580.9	8.6
66	HEAT LOSS DUE TO MOISTURE IN FUEL	14.8	0.1
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1256.7	6.8
68	HEAT LOSS DUE TO COMBUST IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	1.4
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		19.9
72	EFFICIENCY = (100 - Item 71)		80.1

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a(1964)

Test Series:	Pre Long Term Neat Oil	TEST NO 10R	BOILER NO. 3 DATE 10/7/80
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 4 HR
BOILER MAKE & TYPE	Bigelow KS 20	RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A		
PULVERIZER, TYPE & SIZE	N/A	BURNER, SIZE(No)	116-82 (2)
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	99.6
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	325.5
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	210.6
9	STEAM QUALITY % MOISTURE	%	0.73
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	66
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	65.1
12	TEMPERATURE OF FUEL	F	151.4
13	GAS TEMP. LEAVING (Boiler)	F	415.2
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	298.1
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1180.6
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	178.6
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS./LB OF STEAM (ITEM 16 - ITEM 17)	Btu/lb	1002.0
21	HEAT ABS./LB R.H. STEAM (ITEM 19 - ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8542
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	17.2

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	12467.0
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	862.4
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	15985.2
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	12491.7

FLUE GAS ANAL. (BOILER)(ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	12.5
33	O_2	% VOL	4.3
34	CO	% VOL	0.00
35	N_2 (BY DIFFERENCE)	% VOL	83.2
36	EXCESS AIR	%	23.9

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9541
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	256
40	ASH	N/A	44	TOTAL HYDROGEN % wt	11.93
	TOTAL		41	Btu per lb	18535
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP.* ASTM METHOD	N/A		GAS	% VOL
	COAL OR OIL AS FIRED ULTIMATE ANALYSIS		54	CO	N/A
43	CARBON	85.42	55	CH_4 METHANE	N/A
44	HYDROGEN	11.93	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	0.15	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.29	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.45	59	H_2S	N/A
40	ASH	0.059	60	CO_2	N/A
37	MOISTURE	1.7	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	
	COAL PULVERIZATION			TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A
64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29			78.1

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1446.6	7.8
66	HEAT LOSS DUE TO MOISTURE IN FUEL	20.7	0.1
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1305.5	7.0
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	2.0
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		20.0
72	EFFICIENCY = (100 - Item 71)		80.0

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Pre Long Term Neat Oil	TEST NO 11R	BOILER NO. 3 DATE 10/8/80
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 4 HR
BOILER MAKE & TYPE	Bigelow KS 20	RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A		
PULVERIZER, TYPE & SIZE	N/A	BURNER, SIZE(No)	116-82(2)
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	99.3
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	325.5
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R. H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	215.8
9	STEAM QUALITY % MOISTURE	%	0.54
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	73
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	71.0
12	TEMPERATURE OF FUEL	F	149.5
13	GAS TEMP. LEAVING (Boiler)	F	505.7
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	297.8
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1182.2
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	183.8
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 - ITEM 17)	Btu/lb	998.4
21	HEAT ABS/LB R.H. STEAM (ITEM 19 - ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8542
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	17.0

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	19227.6
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1353.6
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	25089.0
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	19197.1

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	12.7
33	O_2	% VOL	4.0
34	CO	% VOL	0.00
35	N_2 (BY DIFFERENCE)	% VOL	83.3
36	EXCESS AIR	%	21.8

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9541
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	262
40	ASH	N/A	44	TOTAL HYDROGEN % wt	11.93
	TOTAL		41	Btu per lb	18535
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP.* ASTM METHOD	N/A		GAS	% VOL
	COAL OR OIL AS FIRED ULTIMATE ANALYSIS		54	CO	N/A
43	CARBON	85.42	55	CH_4 METHANE	N/A
44	HYDROGEN	11.93	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	0.15	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.29	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.45	59	H_2S	N/A
40	ASH	0.059	60	CO_2	N/A
37	MOISTURE	1.7	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	
	COAL PULVERIZATION			TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A
64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29		76.5	

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1769.0	9.5
66	HEAT LOSS DUE TO MOISTURE IN FUEL	21.3	0.1
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1344.6	7.2
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	1.3
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		21.2
72	EFFICIENCY = (100 - Item 71)		78.8

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series: Pre Long Term Neat Oil	TEST NO 12R	BOILER NO. 3	DATE 10/8/80
OWNER OF PLANT U.S. Coast Guard	LOCATION New London, CT		
TEST CONDUCTED BY Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 4 HR	
BOILER MAKE & TYPE Bigelow KS 20	RATED CAPACITY 28,500 lbs/hr		
STOKER TYPE & SIZE N/A			
PULVERIZER, TYPE & SIZE N/A	BURNER, SIZE(No) 116-82 (2)		
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A, SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	99.9
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	324.9
6	STEAM TEMPERATURE AT R. H. INLET	F	N/A
7	STEAM TEMPERATURE AT R. H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	215.1
9	STEAM QUALITY % MOISTURE	%	0.60
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	78
11	TEMP. AIR FOR COMBUSTION (This is Reference Temperature) †	F	74.8
12	TEMPERATURE OF FUEL	F	147.2
13	GAS TEMP. LEAVING (Boiler)	F	534.0
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	298.3
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1181.8
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	183.1
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	998.7
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8542
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	16.0

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	24693.6
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1711.0
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	31712.5
30	HEAT OUTPUT IN BLOW DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	24661.3

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	13.5
33	O_2	% VOL	2.9
34	CO	% VOL	0.00
35	N_2 (BY DIFFERENCE)	% VOL	83.6
36	EXCESS AIR	%	14.9

FUEL DATA

No.	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

No.	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	85.42
44	HYDROGEN	11.93
45	OXYGEN	0.15
46	NITROGEN	0.29
47	SULPHUR	0.45
40	ASH	0.059
37	MOISTURE	1.7
	TOTAL	

No.	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

No.	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9541
53	VISCOSITY AT SSU* BURNER	276
44	TOTAL HYDROGEN % wt	11.93
41	Btu per lb	18535

No.	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	77.8

No.	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1762.9	9.5
66	HEAT LOSS DUE TO MOISTURE IN FUEL	21.4	0.1
67	HEAT LOSS DUE TO H_2O FROM COMB. OF H_2	1354.7	7.3
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	1.0
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		21.0
72	EFFICIENCY = (100 – Item 71)		79.0

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Post Long Term Neat Oil	TEST NO 1	BOILER NO. 3	DATE 5/4/81	
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT		
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST	Measure Efficiency	DURATION	4 HR
BOILER MAKE & TYPE	Bigelow KS 20			RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A				
PULVERIZER, TYPE & SIZE	N/A			BURNER, SIZE(No)	116-82 (2)
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A	SIZE AS FIRED	N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	99
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	328.0
6	STEAM TEMPERATURE AT R. H. INLET	F	N/A
7	STEAM TEMPERATURE AT R. H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	221.5
9	STEAM QUALITY % MOISTURE	%	0.64
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	76
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	76.0
12	TEMPERATURE OF FUEL	F	119.1
13	GAS TEMP. LEAVING (Boiler)	F	411.5
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	297.6
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1181.3
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	189.5
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 - ITEM 17)	Btu/lb	991.8
21	HEAT ABS/LB R.H. STEAM (ITEM 19 - ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.87
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	18.5

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	11143.0
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	733.0
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	14091.8
30	HEAT OUTPUT IN BLOW DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	11051.4

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	11.8
33	O_2	% VOL	5.2
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	83.0
36	EXCESS AIR	%	30.5

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp Gravity	0.9194
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	89
40	ASH	N/A	44	TOTAL HYDROGEN % wt	12.26
	TOTAL		41	Btu per lb	19224
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP. ASTM METHOD	N/A		GAS	% VOL

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS			GAS	% VOL
43	CARBON	87.00	54	CO	N/A
44	HYDROGEN	12.26	55	CH_4 METHANE	N/A
45	OXYGEN	0.09	56	C_2H_2 ACETYLENE	N/A
46	NITROGEN	0.19	57	C_2H_4 ETHYLENE	N/A
47	SULPHUR	0.37	58	C_2H_6 ETHANE	N/A
40	ASH	0.003	59	H_2S	N/A
37	MOISTURE	0.09	60	CO_2	N/A
			61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	

	COAL PULVERIZATION				
				TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	78.4

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1490	7.8
66	HEAT LOSS DUE TO MOISTURE IN FUEL	1	0.0
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1328	6.9
68	HEAT LOSS DUE TO COMBUST IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	2.3
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		19.9
72	EFFICIENCY = (100 - Item 71)		80.1

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series: Post Long Term Neat Oil	TEST NO 2	BOILER NO. 3	DATE 5/5/81
OWNER OF PLANT U.S. Coast Guard	LOCATION New London, CT		
TEST CONDUCTED BY Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 4.75 HR	
BOILER MAKE & TYPE Bigelow KS 20	RATED CAPACITY 28,500 lbs/hr		
STOKER TYPE & SIZE N/A			
PULVERIZER, TYPE & SIZE N/A	BURNER, SIZE(No) 116-82 (2)		
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A · SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	100
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	327.9
6	STEAM TEMPERATURE AT R. H. INLET	F	N/A
7	STEAM TEMPERATURE AT R. H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	220.2
9	STEAM QUALITY % MOISTURE	%	0.55
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	70
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	77.3
12	TEMPERATURE OF FUEL	F	120.6
13	GAS TEMP. LEAVING (Boiler)	F	414.4
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	298.4
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1182.3
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	188.2
18	ENTHALPY OF REHEATED STEAM R. H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	994.1
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.87
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	18.2

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	11349.9
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	744.8
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	14318.9
30	HEAT OUTPUT IN BLOW DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	11282.4

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	12.0
33	O_2	% VOL	5.0
34	CO	% VOL	0.03
35	N_2 (BY DIFFERENCE)	% VOL	83.0
36	EXCESS AIR	%	28.9

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9194
53	VISCOSITY AT SSU* BURNER	124
44	TOTAL HYDROGEN % wt	12.26
41	Btu per lb	19224

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	87.00
44	HYDROGEN	12.26
45	OXYGEN	0.09
46	NITROGEN	0.19
47	SULPHUR	0.37
40	ASH	0.003
37	MOISTURE	0.09
	TOTAL	

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	78.8

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1471	7.6
66	HEAT LOSS DUE TO MOISTURE IN FUEL	1	0.0
67	HEAT LOSS DUE TO H_2O FROM COMB. OF H_2	1328	6.9
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	2.2
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		19.8
72	EFFICIENCY (100 – Item 71)		80.2

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Post Long Term Neat Oil	TEST NO	3	BOILER NO.	3	DATE	5/5/81
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT				
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST	Measure Efficiency	DURATION	4.25 HR		
BOILER MAKE & TYPE	Bigelow KS 20	RATED CAPACITY	28,500 lbs/hr				
STOKER TYPE & SIZE	N/A						
PULVERIZER, TYPE & SIZE	N/A	BURNER, SIZE (No)	116-82 (2)				
FUEL USED	Oil	MINE	N/A	COUNTY	N/A	STATE	N/A
SIZE AS FIRED	N/A						

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	101
2	STEAM PRESSURE AT S.H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R.H. INLET	psia	N/A
4	STEAM PRESSURE AT R.H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	328.3
6	STEAM TEMPERATURE AT R.H. INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	219.7
9	STEAM QUALITY % MOISTURE	%	0.54
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	79
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	81.9
12	TEMPERATURE OF FUEL	F	120.2
13	GAS TEMP. LEAVING (Boiler)	F	415.9
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	299.1
16	ENTHALPY OF (SATURATED) STM	Btu/lb	1182.5
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	187.7
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R.H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	994.8
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.87
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	19.1

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	11515.2
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	752.7
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	14469.4
30	HEAT OUTPUT IN BLOW DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	11455.3

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	11.4
33	O_2	% VOL	5.9
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.7
36	EXCESS AIR	%	36.2

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9194
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	145
40	ASH	N/A	44	TOTAL HYDROGEN % wt	12.26
	TOTAL		41	Btu per lb	19224
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP.* ASTM METHOD	N/A		GAS	% VOL
	COAL OR OIL AS FIRED ULTIMATE ANALYSIS		54	CO	N/A
43	CARBON	87.00	55	CH_4 METHANE	N/A
44	HYDROGEN	12.26	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	0.09	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.19	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.37	59	H_2S	N/A
40	ASH	0.003	60	CO_2	N/A
37	MOISTURE	0.09	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	
	COAL PULVERIZATION			TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A
64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29			79.2

	HEAT LOSS EFFICIENCY	Btu/lb A.F. FUEL	% of A.F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1534	8.0
66	HEAT LOSS DUE TO MOISTURE IN FUEL	1	0.0
67	HEAT LOSS DUE TO H_2O FROM COMB. OF H_2	1323	6.9
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	2.2
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		20.1
72	EFFICIENCY = (100 – Item 71)		79.9

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Post Long Term Neat Oil	TEST NO 4	BOILER NO. 3 DATE 5/6/81
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST	Measure Efficiency DURATION 4 HR
BOILER MAKE & TYPE	Bigelow KS 20	RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A		
PULVERIZER, TYPE & SIZE	N/A	BURNER, SIZE	(No)116-82 (2)
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	105
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	329.6
6	STEAM TEMPERATURE AT R. H. INLET	F	N/A
7	STEAM TEMPERATURE AT R. H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	212.0
9	STEAM QUALITY % MOISTURE	%	1.34
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	75
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	77.5
12	TEMPERATURE OF FUEL	F	121.6
13	GAS TEMP. LEAVING (Boiler)	F	689.9
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	302.1
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1176.2
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	180.0
18	ENTHALPY OF REHEATED STEAM R. H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS./LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	996.2
21	HEAT ABS./LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.87
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	17.2

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	31618.7
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	2235.1
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	42967.0
30	HEAT OUTPUT IN BLOW DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	314976

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	12.7
33	O_2	% VOL	3.9
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	83.4
36	EXCESS AIR	%	21.1

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9194
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	136
40	ASH	N/A	44	TOTAL HYDROGEN % wt	12.26
	TOTAL		41	Btu per lb	19224
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP. ASTM METHOD	N/A		GAS	% VOL
	COAL OR OIL AS FIRED ULTIMATE ANALYSIS		54	CO	N/A
43	CARBON	87.00	55	CH_4 METHANE	N/A
44	HYDROGEN	12.26	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	0.09	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.19	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.37	59	H_2S	N/A
40	ASH	0.003	60	CO_2	N/A
37	MOISTURE	0.09	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	
	COAL PULVERIZATION			TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT % (ITEM 31 × 100 / ITEM 29)	73.3

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	2535	13.2
66	HEAT LOSS DUE TO MOISTURE IN FUEL	1	0.0
67	HEAT LOSS DUE TO H_2O FROM COMB. OF H_2	1470	7.6
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	0.8
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		24.7
72	EFFICIENCY (100 – Item 71)		75.4

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Post Long Term Neat Oil	TEST NO 5	BOILER NO. 3 DATE 5/6/81
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 4 H
BOILER MAKE & TYPE	Bigelow KS 20	RATED CAPACITY	28,500 lbs/h
STOKER TYPE & SIZE	N/A		
PULVERIZER, TYPE & SIZE	N/A	BURNER, SIZE(No)	116-82 (2
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	105
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	329.7
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	212.1
9	STEAM QUALITY % MOISTURE	%	1.13
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	79
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	75.9
12	TEMPERATURE OF FUEL	F	121.1
13	GAS TEMP. LEAVING (Boiler)	F	611.4
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	302.0
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1178.0
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	180.1
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	997.9
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.87
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	16.2

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	28337.2
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1949.0
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	37467.2
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	28276.4

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	13.6
33	O_2	% VOL	3.3
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	83.1
36	EXCESS AIR	%	17.4

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Da
38	VOL MATTER	N/A	52	Sp. Gravity	0.919
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	140
40	ASH	N/A	44	TOTAL HYDROGEN % wt	12.26
	TOTAL		41	Btu per lb	19224
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP.* ASTM METHOD	N/A		GAS	% VOL
	COAL OR OIL AS FIRED ULTIMATE ANALYSIS		54	CO	N/A
43	CARBON	87.00	55	CH_4 METHANE	N/A
44	HYDROGEN	12.26	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	0.09	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.19	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.37	59	H_2S	N/A
40	ASH	0.003	60	CO_2	N/A
37	MOISTURE	0.09	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	
	COAL PULVERIZATION			TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	75.5

	HEAT LOSS EFFICIENCY	Btu/lb A.F. FUEL	% of A.F. FUEL
65	HEAT LOSS DUE TO DRY GAS	2078	10.8
66	HEAT LOSS DUE TO MOISTURE IN FUEL	1	0.0
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1431	7.4
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	0.9
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		22.2
72	EFFICIENCY = (100 – Item 71)		77.8

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Post Long Term Neat Oil	TEST NO 6	BOILER NO. 3	DATE 5/7/81	
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT		
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST	Measure Efficiency	DURATION 4 HR	
BOILER MAKE & TYPE	Bigelow KS 20	RATED CAPACITY	28,500 lbs/hr		
STOKER TYPE & SIZE	N/A				
PULVERIZER, TYPE & SIZE	N/A	BURNER, SIZE(No)	116-82 (2)		
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A	SIZE AS FIRED N/A	

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	105
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	329.7
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R. H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	210.6
9	STEAM QUALITY % MOISTURE	%	0.50
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	75
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	72.4
12	TEMPERATURE OF FUEL	F	123.1
13	GAS TEMP. LEAVING (Boiler)	F	653.0
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	301.9
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1183.6
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	178.6
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	1005.0
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.87
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	16.8

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	30812.5
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	2149.3
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	41317.4
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT [(Item 26×Item 20)+(Item 27×Item 21)+Item 30] / 1000	kB/hr	30965.5

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	13.1
33	O_2	% VOL	4.1
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.8
36	EXCESS AIR	%	22.6

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	87.00
44	HYDROGEN	12.26
45	OXYGEN	0.09
46	NITROGEN	0.19
47	SULPHUR	0.37
40	ASH	0.003
37	MOISTURE	0.09
	TOTAL	

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9194
53	VISCOSITY AT SSU* BURNER	132
44	TOTAL HYDROGEN % wt	12.26
41	Btu per lb	19224

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT % (ITEM 31 × 100 / ITEM 29)	74.9

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	2336	12.1
66	HEAT LOSS DUE TO MOISTURE IN FUEL	1	0.0
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1456	7.6
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	0.8
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		23.6
72	EFFICIENCY = (100 – Item 71)		76.4

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series: Post Long Term Neat Oil	TEST NO 7	BOILER NO. 3	DATE 5/7/81
OWNER OF PLANT U.S. Coast Guard	LOCATION New London, CT		
TEST CONDUCTED BY Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 4 H	
BOILER MAKE & TYPE Bigelow KS 20		RATED CAPACITY 28,500 lbs/h	
STOKER TYPE & SIZE N/A			
PULVERIZER, TYPE & SIZE N/A		BURNER, SIZE (No) 116-82 (2	
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	103
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	329.1
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	209.8
9	STEAM QUALITY % MOISTURE	%	0.31
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	76
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	78.9
12	TEMPERATURE OF FUEL	F	123.7
13	GAS TEMP. LEAVING (Boiler)	F	588.8
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	300.6
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1184.9
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	177.8
18	ENTHALPY OF REHEATED STEAM R. H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	1007.1
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.87
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	18.1

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	25664.4
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1785.3
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	34320.9
30	HEAT OUTPUT IN BLOW DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	25847.0

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	12.1
33	O_2	% VOL	5.2
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.7
36	EXCESS AIR	%	30.6

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	87.00
44	HYDROGEN	12.26
45	OXYGEN	0.09
46	NITROGEN	0.19
47	SULPHUR	0.37
40	ASH	0.003
37	MOISTURE	0.09
	TOTAL	

	OIL	
51	FLASH POINT F*	No Da
52	Sp. Gravity	0.919
53	VISCOSITY AT SSU* BURNER	133
44	TOTAL HYDROGEN % wt	12.2
41	Btu per lb	1922

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT % (ITEM 31 × 100 / ITEM 29)	75.

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A F FUEL
65	HEAT LOSS DUE TO DRY GAS	2212	11.5
66	HEAT LOSS DUE TO MOISTURE IN FUEL	1	0.0
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1416	7.4
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	1.0
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		22.9
72	EFFICIENCY – (100 – Item 71)		77.1

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Post Long Term Neat Oil	TEST NO	9	BOILER NO 3	DATE 5/11/81
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT		
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST	Measure Efficiency	DURATION	4 HR
BOILER MAKE & TYPE	Bigelow KS 20			RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A				
PULVERIZER TYPE & SIZE	N/A			BURNER, SIZE(No)	116-82 (2)
FUEL USED	Oil	MINE N/A	COUNTY N/A	STATE N/A	SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	101
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	328.5
6	STEAM TEMPERATURE AT R. H. INLET	F	N/A
7	STEAM TEMPERATURE AT R. H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	181.8
9	STEAM QUALITY % MOISTURE	%	0.48
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	71
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	67.3
12	TEMPERATURE OF FUEL	F	120.7
13	GAS TEMP. LEAVING (Boiler)	F	461.1
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	299.1
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1183.0
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	149.8
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 - ITEM 17)	Btu/lb	1033.2
21	HEAT ABS/LB R.H. STEAM (ITEM 19 - ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.87
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	18.2

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	15211.6
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1061.4
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	20405.5
30	HEAT OUTPUT IN BLOW DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	15717.4

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	12.0
33	O_2	% VOL	5.1
34	CO	% VOL	0.02
35	N_2 (BY DIFFERENCE)	% VOL	82.9
36	EXCESS AIR	%	29.7

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9194
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU BURNER	147
40	ASH	N/A	44	TOTAL HYDROGEN % wt	12.26
	TOTAL		41	Btu per lb	19224
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP ASTM METHOD	N/A			

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS			GAS	% VOL
43	CARBON	87.00	54	CO	N/A
44	HYDROGEN	12.26	55	CH_4 METHANE	N/A
45	OXYGEN	0.09	56	C_2H_2 ACETYLENE	N/A
46	NITROGEN	0.19	57	C_2H_4 ETHYLENE	N/A
47	SULPHUR	0.37	58	C_2H_6 ETHANE	N/A
40	ASH	0.003	59	H_2S	N/A
37	MOISTURE	0.09	60	CO_2	N/A
			61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	
				TOTAL HYDROGEN % wt	N/A

	COAL PULVERIZATION				
48	GRINDABILITY INDEX	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A
64	INPUT-OUTPUT EFFICIENCY OF UNIT %			ITEM 31 × 100 / ITEM 29	77.0

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1720	8.9
66	HEAT LOSS DUE TO MOISTURE IN FUEL	1	0.0
67	HEAT LOSS DUE TO H_2O FROM COMB. OF H_2	1363	7.1
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	1.6
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		20.7
72	EFFICIENCY (100 - Item 71)		79.3

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Post Long Term Neat Oil	TEST NO 10R	BOILER NO. 3 DATE 5/12/81
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 4 HR
BOILER MAKE & TYPE	Bigelow KS 20	RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A		
PULVERIZER, TYPE & SIZE	N/A	BURNER, SIZE (No)	116-82 (2)
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	102
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	328.4
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R. H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	214.4
9	STEAM QUALITY % MOISTURE	%	0.47
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	76
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	77.4
12	TEMPERATURE OF FUEL	F	122.8
13	GAS TEMP. LEAVING (Boiler)	F	496.1
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	299.9
16	ENTHALPY OF (SATURATED) STM	Btu/lb	1183.3
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	182.4
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 - ITEM 17)	Btu/lb	1000.9
21	HEAT ABS/LB R.H. STEAM (ITEM 19 - ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.87
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	17.6

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	18693.1
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1280.6
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	24618.1
30	HEAT OUTPUT IN BLOW DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	18710.5

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	12.4
33	O_2	% VOL	4.4
34	CO	% VOL	0.02
35	N_2 (BY DIFFERENCE)	% VOL	83.2
36	EXCESS AIR	%	24.5

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9194
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	135
40	ASH	N/A	44	TOTAL HYDROGEN % wt	12.26
	TOTAL		41	Btu per lb	19224
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP.* ASTM METHOD	N/A		GAS	% VOL
	COAL OR OIL AS FIRED ULTIMATE ANALYSIS		54	CO	N/A
43	CARBON	87.00	55	CH_4 METHANE	N/A
44	HYDROGEN	12.26	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	0.09	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.19	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.37	59	H_2S	N/A
40	ASH	0.003	60	CO_2	N/A
37	MOISTURE	0.09	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	
	COAL PULVERIZATION			TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A
64	INPUT-OUTPUT EFFICIENCY OF UNIT %			ITEM 31 × 100 / ITEM 29	76.0

	HEAT LOSS EFFICIENCY	Btu/lb A.F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1772	9.2
66	HEAT LOSS DUE TO MOISTURE IN FUEL	1	0.0
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1370	7.1
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	1.4
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		20.7
72	EFFICIENCY = (100 - Item 71)		79.3

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series: Post Long Term Neat Oil	TEST NO 11	BOILER NO. 3	DATE 5/12/81
OWNER OF PLANT U.S. Coast Guard	LOCATION New London, CT		
TEST CONDUCTED BY Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 3.5 HR	
BOILER MAKE & TYPE Bigelow KS 20	RATED CAPACITY 28,500 lbs/hr		
STOKER TYPE & SIZE N/A			
PULVERIZER, TYPE & SIZE N/A	BURNER, SIZE(No) 116-82 (2)		
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A / SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	102
2	STEAM PRESSURE AT S.H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R.H. INLET	psia	N/A
4	STEAM PRESSURE AT R.H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	328.4
6	STEAM TEMPERATURE AT R.H. INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	219.6
9	STEAM QUALITY % MOISTURE	%	0.45
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	75
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	72.6
12	TEMPERATURE OF FUEL	F	120.8
13	GAS TEMP. LEAVING (Boiler)	F	519.0
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	299.9
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1183.5
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	187.6
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R.H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	995.9
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.87
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	17.2

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	20757.5
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1398.7
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	26899.1
30	HEAT OUTPUT IN BLOW DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	20672.8

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	12.7
33	O_2	% VOL	4.1
34	CO	% VOL	0.02
35	N_2 (BY DIFFERENCE)	% VOL	83.2
36	EXCESS AIR	%	22.4

FUEL DATA

No.	COAL AS FIRED PROX. ANALYSIS	% wt	No.	OIL	
37	MOISTURE	N/A	51	FLASH POINT F	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9194
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU BURNER	148
40	ASH	N/A	44	TOTAL HYDROGEN % wt	12.26
	TOTAL		41	Btu per lb	19224
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP ASTM METHOD	N/A		GAS	% VOL

No.	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	% wt	No.	GAS	% VOL
			54	CO	N/A
43	CARBON	87.00	55	CH_4 METHANE	N/A
44	HYDROGEN	12.26	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	0.09	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.19	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.37	59	H_2S	N/A
40	ASH	0.003	60	CO_2	N/A
37	MOISTURE	0.09	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	
	COAL PULVERIZATION			TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A
64	INPUT-OUTPUT EFFICIENCY OF UNIT %			ITEM 31 × 100 / ITEM 29	76.9

HEAT LOSS EFFICIENCY

		Btu/lb A.F. FUEL	% of A.F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1847	9.6
66	HEAT LOSS DUE TO MOISTURE IN FUEL	1	0.0
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1387	7.2
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	1.2
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		21.1
72	EFFICIENCY = (100 – Item 71)		78.9

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Post Long Term Neat Oil	TEST NO	12	BOILER NO. 3	DATE 5/13/82
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT		
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST	Measure Efficiency	DURATION	4 Hr
BOILER MAKE & TYPE	Bigelow KS 20			RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A				
PULVERIZER, TYPE & SIZE	N/A			BURNER, SIZE (No)	116-82 (1)
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A	SIZE AS FIRED	N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	102
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	328.9
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	206.7
9	STEAM QUALITY % MOISTURE	%	0.32
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	76
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	72.0
12	TEMPERATURE OF FUEL	F	117.4
13	GAS TEMP. LEAVING (Boiler)	F	356.2
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	299.5
16	ENTHALPY OF (SATURATED STM.	Btu/lb	1184.5
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	174.7
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	1009.8
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.87
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	19.4

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	8546.3
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	570.6
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	10968.8
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	8630.4

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	11.2
33	O_2	% VOL	6.2
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.6
36	EXCESS AIR	%	38.8

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	87.00
44	HYDROGEN	12.26
45	OXYGEN	0.09
46	NITROGEN	0.19
47	SULPHUR	0.37
40	ASH	0.003
37	MOISTURE	0.09
	TOTAL	

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A
64	INPUT-OUTPUT EFFICIENCY OF UNIT % (ITEM 31 × 100 / ITEM 29)	78.7

	OIL	
51	FLASH POINT F*	No Dat
52	Sp. Gravity	0.9194
53	VISCOSITY AT SSU* BURNER	161
44	TOTAL HYDROGEN % wt	12.26
41	Btu per lb	19224

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

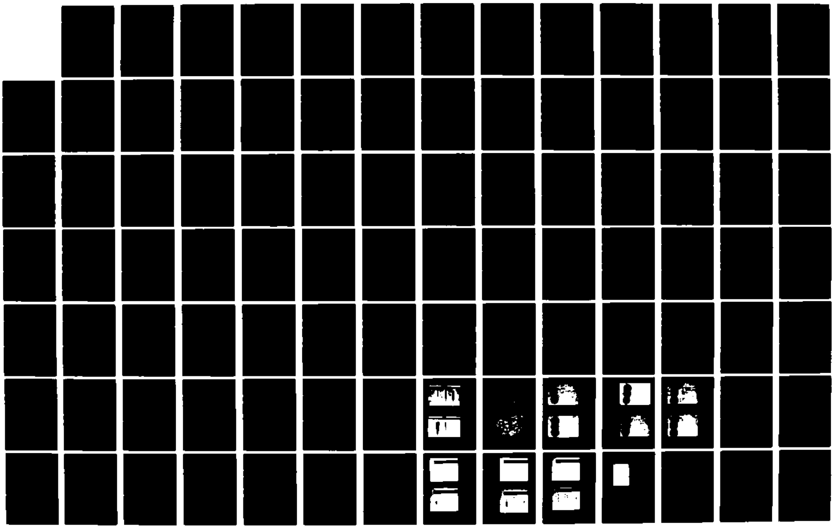
	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1327	6.9
66	HEAT LOSS DUE TO MOISTURE IN FUEL	1	0.0
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1304	6.8
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	2.9
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		19.6
72	EFFICIENCY = (100 – Item 71)		80.4

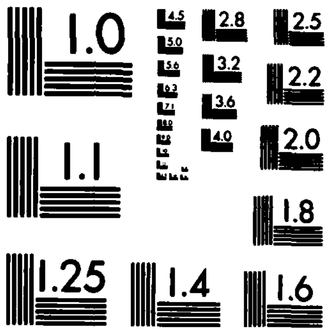
* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

AD-A121 011 SHORESIDE BOILER DEMONSTRATION OF FUEL-WATER EMULSIONS 3/4
(U) SEAWORTHY ENGINE SYSTEMS INC ESSEX CT
R W CASS ET AL. AUG 82 USCG-D-04-82 DTCG23-80-C-20001

UNCLASSIFIED F/G 21/4 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a(1964)

Test Series:	Interim Baseline Neat Oil	TEST NO 1	BOILER NO. 3 DATE 6/8/81
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST	Measure Efficiency DURATION 4 HR
BOILER MAKE & TYPE	Bigelow KS 20	RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A		
PULVERIZER, TYPE & SIZE	N/A	BURNER, SIZE(No)	116-82 (1)
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	100.2
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	326.5
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	157.9
9	STEAM QUALITY % MOISTURE	%	0.31
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	79
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	75.9
12	TEMPERATURE OF FUEL	F	121.2
13	GAS TEMP. LEAVING (Boiler)	F	349.0
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	298.5
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1184.4
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	125.9
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	1058.6
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8668
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	20.6

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	8150.4
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	561.2
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	10689.6
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	8627.6

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	10.5
33	O_2	% VOL	6.9
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.6
36	EXCESS AIR	%	45.2

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	86.68
44	HYDROGEN	12.14
45	OXYGEN	0.40
46	NITROGEN	0.22
47	SULPHUR	0.44
40	ASH	0.001
37	MOISTURE	0.12
	TOTAL	

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9254
53	VISCOSITY AT SSU* BURNER	216
44	TOTAL HYDROGEN % wt	12.14
41	Btu per lb	19046

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	80.7

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1351.9	7.1
66	HEAT LOSS DUE TO MOISTURE IN FUEL	1.4	0.01
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1282.9	6.7
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	2.9
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		19.7
72	EFFICIENCY = (100 – Item 71)		80.3

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Interim Baseline Neat Oil	TEST NO	2R	BOILER NO.	3	DATE	6/8/81
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT				
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST	Measure Efficiency	DURATION	4 HR		
BOILER MAKE & TYPE	Bigelow KS 20	RATED CAPACITY	28,500 lbs/hr				
STOKER TYPE & SIZE	N/A						
PULVERIZER, TYPE & SIZE	N/A	BURNER, SIZE (No)	116-82 (2)				
FUEL USED	Oil	MINE	N/A	COUNTY	N/A	STATE	N/A
SIZE AS FIRED	N/A						

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	98.3
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	325.4
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R. H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	183.2
9	STEAM QUALITY % MOISTURE	%	0.47
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	84
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	77.9
12	TEMPERATURE OF FUEL	F	125.9
13	GAS TEMP. LEAVING (Boiler)	F	398.2
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	297.1
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1182.7
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	151.2
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 - ITEM 17)	Btu/lb	1031.5
21	HEAT ABS/LB R.H. STEAM (ITEM 19 - ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8668
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	19.4

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	11869.8
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	796.2
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	15163.8
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	12243.4

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	11.2
33	O_2	% VOL	6.2
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.6
36	EXCESS AIR	%	38.8

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	86.68
44	HYDROGEN	12.14
45	OXYGEN	0.40
46	NITROGEN	0.22
47	SULPHUR	0.44
40	ASH	0.001
37	MOISTURE	0.12
	TOTAL	

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9254
53	VISCOSITY AT SSU* BURNER	192
44	TOTAL HYDROGEN % wt	12.14
41	Btu per lb	19046

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	80.7

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1490.7	7.8
66	HEAT LOSS DUE TO MOISTURE IN FUEL	1.4	0.01
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1305.8	6.9
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	2.1
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		19.8
72	EFFICIENCY - (100 - Item 71)		80.2

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Interim Baseline Neat Oil	TEST NO 3	BOILER NO. 3	DATE 6/9/81	
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT		
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST	Measure Efficiency	DURATION	4 HR
BOILER MAKE & TYPE	Bigelow KS 20			RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A				
PULVERIZER, TYPE & SIZE	N/A			BURNER, SIZE(No)	116-82 (2)
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A	SIZE AS FIRED	N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	97.4
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	324.9
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R. H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	216.2
9	STEAM QUALITY % MOISTURE	%	0.48
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	83
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	82.8
12	TEMPERATURE OF FUEL	F	119.3
13	GAS TEMP. LEAVING (Boiler)	F	423.5
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	296.4
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1182.4
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	184.2
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 - ITEM 17)	Btu/lb	998.2
21	HEAT ABS/LB R.H. STEAM (ITEM 19 - ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8668
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	18.4

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	14492.8
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	937.4
29	TOTAL HEAT INPUT (Item 28 x Item 41) / 1000	kB/hr	178543
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 + Item 20) + (Item 27 + Item 21) + Item 30 / 1000	kB/hr	14466.7

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	11.8
33	O_2	% VOL	5.5
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.7
36	EXCESS AIR	%	32.9

FUEL DATA

No.	COAL AS FIRED PROX. ANALYSIS	% wt	No.	OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9254
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	232
40	ASH	N/A	44	TOTAL HYDROGEN % wt	12.14
	TOTAL		41	Btu per lb	19046
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP.* ASTM METHOD	N/A		GAS	% VOL

No.	COAL OR OIL AS FIRED ULTIMATE ANALYSIS		No.	GAS	% VOL
			54	CO	N/A
43	CARBON	86.68	55	CH_4 METHANE	N/A
44	HYDROGEN	12.14	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	0.40	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.22	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.44	59	H_2S	N/A
40	ASH	0.001	60	CO_2	N/A
37	MOISTURE	0.12	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	

No.	COAL PULVERIZATION		No.		
				TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A
64	INPUT-OUTPUT EFFICIENCY OF UNIT % (ITEM 31 x 100 / ITEM 29)				81.0

No.	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1508.5	7.9
66	HEAT LOSS DUE TO MOISTURE IN FUEL	1.4	0.01
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1313.4	6.9
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	1.8
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		19.6
72	EFFICIENCY = (100 - Item 71)		80.4

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4 1.o (1964)

Test Series:	Interim Baseline Neat Oil	TEST NO.	4	BOILER NO. 3	DATE 6/10/81
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT		
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST	Measure Efficiency	DURATION	4.25 HR
BOILER MAKE & TYPE	Bigelow KS 20			RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A				
PULVERIZER, TYPE & SIZE	N/A			BURNER, SIZE (No)	116-82 (2)
FUEL USED Oil	MINE N/A	COUNTY N/A		STATE N/A	SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	99.0
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	325.2
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	185.4
9	STEAM QUALITY % MOISTURE	%	0.54
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	81
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	77.1
12	TEMPERATURE OF FUEL	F	120.4
13	GAS TEMP. LEAVING (Boiler)	F	468.0
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	297.6
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1182.2
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	153.4
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS./LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	1028.8
21	HEAT ABS./LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8668
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	18.2

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	18118.0
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1237.5
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	23569.3
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	18639.2

FLUE GAS ANAL. (BOILER)(ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	12.0
33	O_2	% VOL	5.2
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.8
36	EXCESS AIR	%	30.5

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9254
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	210
40	ASH	N/A	44	TOTAL HYDROGEN % wt	12.14
	TOTAL		41	Btu per lb	19046
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP.* ASTM METHOD	N/A		GAS	% VOL
	COAL OR OIL AS FIRED ULTIMATE ANALYSIS		54	CO	N/A
43	CARBON	86.68	55	CH_4 METHANE	N/A
44	HYDROGEN	12.14	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	0.40	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.22	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.44	59	H_2S	N/A
40	ASH	0.001	60	CO_2	N/A
37	MOISTURE	0.12	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	
	COAL PULVERIZATION			TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	79.1

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1703.1	8.9
66	HEAT LOSS DUE TO MOISTURE IN FUEL	1.5	0.01
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1342.3	7.0
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	1.4
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		20.4
72	EFFICIENCY = (100 – Item 71)		79.6

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Interim Baseline Neat Oil	TEST NO	6	BOILER NO. 3	DATE 6/10/81
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT		
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST	Measure Efficiency	DURATION	4 HR
BOILER MAKE & TYPE	Bigelow KS 20			RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A				
PULVERIZER, TYPE & SIZE	N/A			BURNER, SIZE(No)	116-82 (2)
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A	SIZE AS FIRED	N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	100.0
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	325.4
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	190.9
9	STEAM QUALITY % MOISTURE	%	0.43
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	81
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	75.1
12	TEMPERATURE OF FUEL	F	119.0
13	GAS TEMP. LEAVING (Boiler)	F	523.6
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	298.4
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1183.3
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	158.9
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	1024.4
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8668
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	17.6

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	237706
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1618.2
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	308196
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	243514

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	12.4
33	O_2	% VOL	4.8
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.8
36	EXCESS AIR	%	27.5

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9254
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	232
40	ASH	N/A	44	TOTAL HYDROGEN % wt	12.14
	TOTAL		41	Btu per lb	19046
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP.* ASTM METHOD	N/A		GAS	% VOL
	COAL OR OIL AS FIRED ULTIMATE ANALYSIS		54	CO	N/A
43	CARBON	86.68	55	CH_4 METHANE	N/A
44	HYDROGEN	12.14	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	0.40	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.22	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.44	59	H_2S	N/A
40	ASH	0.001	60	CO_2	N/A
37	MOISTURE	0.12	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	
	COAL PULVERIZATION			TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	79.0

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1894.1	9.9
66	HEAT LOSS DUE TO MOISTURE IN FUEL	1.5	0.01
67	HEAT LOSS DUE TO H_2O FROM COMB. OF H_2	1372.9	7.2
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	1.1
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		21.2
72	EFFICIENCY = (100 – Item 71)		78.8

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Interim Baseline Neat Oil	TEST NO	7	BOILER NO. 3	DATE 6/12/81
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT		
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST	Measure Efficiency	DURATION	4.25 HR
BOILER MAKE & TYPE	Bigelow KS 20			RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A				
PULVERIZER, TYPE & SIZE	N/A			BURNER, SIZE (No)	116-82 (2)
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A	SIZE AS FIRED	N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	98.3
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	324.2
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	193.2
9	STEAM QUALITY % MOISTURE	%	0.58
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	86
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	83.5
12	TEMPERATURE OF FUEL	F	121.3
13	GAS TEMP. LEAVING (Boiler)	F	531.8
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	297.1
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1181.6
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	161.2
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	1020.4
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8668
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	18.1

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	25690.8
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1759.2
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	33505.1
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	26216.3

FLUE GAS ANAL. (BOILER)(ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	12.0
33	O_2	% VOL	4.2
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	83.8
36	EXCESS AIR	%	23.0

FUEL DATA

No.	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

No.	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	86.68
44	HYDROGEN	12.14
45	OXYGEN	0.40
46	NITROGEN	0.22
47	SULPHUR	0.44
40	ASH	0.001
37	MOISTURE	0.12
	TOTAL	

No.	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9254
53	VISCOSITY AT SSU* BURNER	196
44	TOTAL HYDROGEN % wt	12.14
41	Btu per lb	19046

No.	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

COAL PULVERIZATION

48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	78.2

HEAT LOSS EFFICIENCY

		Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1950.6	10.2
66	HEAT LOSS DUE TO MOISTURE IN FUEL	1.5	0.01
67	HEAT LOSS DUE TO H_2O FROM COMB. OF H_2	1367.9	7.2
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	1.0
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		21.4
72	EFFICIENCY = (100 – Item 71)		78.6

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series: Interim Baseline Neat Oil	TEST NO. 8	BOILER NO. 3	DATE 6/11/81
OWNER OF PLANT U.S. Coast Guard	LOCATION New London, CT		
TEST CONDUCTED BY Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 4 HR	
BOILER MAKE & TYPE Bigelow KS 20	RATED CAPACITY 28,500 lbs/hr		
STOKER TYPE & SIZE N/A			
PULVERIZER, TYPE & SIZE N/A	BURNER, SIZE (No) 116-82 (2)		
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A	SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	98.8
2	STEAM PRESSURE AT S.H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R.H. INLET	psia	N/A
4	STEAM PRESSURE AT R.H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	323.5
6	STEAM TEMPERATURE AT R.H. INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	214.5
9	STEAM QUALITY % MOISTURE	%	0.67
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	86
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	81.4
12	TEMPERATURE OF FUEL	F	120.3
13	GAS TEMP. LEAVING (Boiler)	F	568.3
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	297.4
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1181.0
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	182.5
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R.H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	998.5
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8668
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	16.7

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	304150
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	2091.0
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	398248
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	303693

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	13.1
33	O_2	% VOL	3.7
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	83.2
36	EXCESS AIR	%	19.8

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	86.68
44	HYDROGEN	12.14
45	OXYGEN	0.40
46	NITROGEN	0.22
47	SULPHUR	0.44
40	ASH	0.001
37	MOISTURE	0.12
	TOTAL	

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9254
53	VISCOSITY AT SSU* BURNER	239
44	TOTAL HYDROGEN % wt	12.14
41	Btu per lb	19046

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT % (ITEM 31 × 100 / ITEM 29)	76.2

	HEAT LOSS EFFICIENCY	Btu/lb A.F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1950.9	10.2
66	HEAT LOSS DUE TO MOISTURE IN FUEL	1.5	0.01
67	HEAT LOSS DUE TO H_2O FROM COMB. OF H_2	1388.8	7.3
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	0.9
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		21.4
72	EFFICIENCY = (100 – Item 71)		78.6

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Pre Long Term Emulsified Oil	TEST NO.	1	BOILER NO. 3	DATE 6/22/81
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT		
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST	Measure Efficiency	DURATION	4 HR
BOILER MAKE & TYPE	Bigelow KS 20			RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A				
PULVERIZER, TYPE & SIZE	N/A			BURNER, SIZE (No)	116-82 (1)
FUEL USED Oil	MINE N/A	COUNTY	N/A	STATE N/A	SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	97.4
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	324.2
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R. H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	219.3
9	STEAM QUALITY % MOISTURE	%	0.32
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	86
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	80.0
12	TEMPERATURE OF FUEL	F	121.2
13	GAS TEMP. LEAVING (Boiler)	F	332.5
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	296.4
16	ENTHALPY OF (SATURATED STM.	Btu/lb	1183.8
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	187.3
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	996.5
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8301
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	17.2

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	7249.6
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	512.7
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	9304.0
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	7224.2

FLUE GAS ANAL. (BOILER)(ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	12.1
33	O_2	% VOL	5.1
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.8
36	EXCESS AIR	%	29.8

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	83.01
44	HYDROGEN	12.20
45	OXYGEN	4.21
46	NITROGEN	0.17
47	SULPHUR	0.40
40	ASH	0.013
37	MOISTURE	5.3
	TOTAL	

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9206
53	VISCOSITY AT SSU* BURNER	113
44	TOTAL HYDROGEN % wt	12.20
41	Btu per lb	18148

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT % (ITEM 31 × 100 / ITEM 29)	77.6

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1045.2	5.6
66	HEAT LOSS DUE TO MOISTURE IN FUEL	61.6	0.34
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1276.3	7.0
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	3.4
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		19.6
72	EFFICIENCY = (100 – Item 71)		80.4

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series: Pre Long Term Emulsified Oil	TEST NO 2 — BOILER NO. 3 — DATE 6/22/81
OWNER OF PLANT: U.S. Coast Guard	LOCATION: New London, CT
TEST CONDUCTED BY: Seaworthy Engine Systems	OBJECTIVE OF TEST: Measure Efficiency — DURATION 4 HR
BOILER MAKE & TYPE: Bigelow KS 20	RATED CAPACITY 28,500 lbs/hr
STOKER TYPE & SIZE: N/A	
PULVERIZER, TYPE & SIZE: N/A	BURNER, SIZE(No) 116-82 (2)
FUEL USED: Oil — MINE N/A	COUNTY N/A — STATE N/A — SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	97.7
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	324.2
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R. H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	221.1
9	STEAM QUALITY % MOISTURE	%	0.47
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	90
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	84.0
12	TEMPERATURE OF FUEL	F	120.7
13	GAS TEMP. LEAVING (Boiler)	F	388.1
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	296.6
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1182.5
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	189.1
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	993.4
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8301
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	16.4

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	11800.1
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	812.8
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	14750.0
30	HEAT OUTPUT IN BLOW DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	11722.7

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	12.8
33	O_2	% VOL	4.4
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.8
36	EXCESS AIR	%	24.7

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9206
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	114
40	ASH	N/A	44	TOTAL HYDROGEN % wt	12.20
	TOTAL		41	Btu per lb	18148
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP.* ASTM METHOD	N/A		GAS	% VOL
	COAL OR OIL AS FIRED ULTIMATE ANALYSIS		54	CO	N/A
43	CARBON	83.01	55	CH_4 METHANE	N/A
44	HYDROGEN	12.20	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	4.21	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.17	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.40	59	H_2S	N/A
40	ASH	0.013	60	CO_2	N/A
37	MOISTURE	5.3	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	
	COAL PULVERIZATION			TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	79.5

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1193.3	6.6
66	HEAT LOSS DUE TO MOISTURE IN FUEL	62.8	0.35
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1300.4	7.2
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	2.2
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		19.2
72	EFFICIENCY = (100 – Item 71)		80.8

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series: Pre Long Term Emulsified Oil TEST NO. 3 BOILER NO. 3 DATE 6/23/81

OWNER OF PLANT U.S. Coast Guard LOCATION New London, CT

TEST CONDUCTED BY Seaworthy Engine Systems OBJECTIVE OF TEST Measure Efficiency DURATION 4 HR

BOILER MAKE & TYPE Bigelow KS 20 RATED CAPACITY 28,500 lbs/hr

STOKER TYPE & SIZE N/A

PULVERIZER, TYPE & SIZE N/A BURNER, SIZE(No)116-82 (2)

FUEL USED Oil MINE N/A COUNTY N/A STATE N/A SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	98.0
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	324.4
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	219.2
9	STEAM QUALITY % MOISTURE	%	0.51
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	91
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	84.3
12	TEMPERATURE OF FUEL	F	121.0
13	GAS TEMP. LEAVING (Boiler)	F	391.2
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	296.8
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1182.3
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	187.2
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	995.1
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8301
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	17.4

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	11553.6
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	810.0
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	14700.8
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	11496.5

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	12.0
33	O_2	% VOL	5.2
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.8
36	EXCESS AIR	%	30.5

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9206
53	VISCOSITY AT SSU* BURNER	115
44	TOTAL HYDROGEN % wt	12.20
41	Btu per lb	18148

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	83.01
44	HYDROGEN	12.20
45	OXYGEN	4.21
46	NITROGEN	0.17
47	SULPHUR	0.40
40	ASH	0.013
37	MOISTURE	5.3
	TOTAL	

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	78.2

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1280.5	7.1
66	HEAT LOSS DUE TO MOISTURE IN FUEL	62.8	0.35
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1301.7	7.2
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	2.2
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		19.8
72	EFFICIENCY = (100 – Item 71)		80.2

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a(1964)

Test Series:	Pre Long Term Emulsified Oil	TEST NO 4	BOILER NO. 3 DATE 6/23/81
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 4 HR
BOILER MAKE & TYPE	Bigelow KS 20	RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A		
PULVERIZER, TYPE & SIZE	N/A	BURNER, SIZE(No)	116-82 (2)
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	98.1
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	324.3
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	220.1
9	STEAM QUALITY % MOISTURE	%	0.50
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	93
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	85.7
12	TEMPERATURE OF FUEL	F	120.7
13	GAS TEMP. LEAVING (Boiler)	F	385.4
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	296.9
16	ENTHALPY OF (SATURATED STM.	Btu/lb	1182.4
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	188.1
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	994.2
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8301
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	17.0

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	114818
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	782.9
29	TOTAL HEAT INPUT (Item 28 x Item 41) / 1000	kB/hr	14207.4
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 x Item 20) + (Item 27 x Item 21) + Item 30 / 1000	kB/hr	114158

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	12.3
33	O_2	% VOL	5.0
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.7
36	EXCESS AIR	%	29.1

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9206
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	117
40	ASH	N/A	44	TOTAL HYDROGEN % wt	12.20
	TOTAL		41	Btu per lb	18148
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP ASTM METHOD	N/A		GAS	% VOL
	COAL OR OIL AS FIRED ULTIMATE ANALYSIS		54	CO	N/A
43	CARBON	83.01	55	CH_4 METHANE	N/A
44	HYDROGEN	12.20	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	4.21	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.17	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.40	59	H_2S	N/A
40	ASH	0.013	60	CO_2	N/A
37	MOISTURE	5.3	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	
	COAL PULVERIZATION			TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 x 100 / ITEM 29	80.4

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1221.6	6.7
66	HEAT LOSS DUE TO MOISTURE IN FUEL	62.6	0.34
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1297.2	7.1
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	2.2
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		19.4
72	EFFICIENCY = (100 – Item 71)		80.6

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Pre Long Term Emulsified Oil
TEST NO.	5
BOILER NO.	3
DATE	6/24/81
OWNER OF PLANT	U.S. Coast Guard
LOCATION	New London, CT
TEST CONDUCTED BY	Seaworthy Engine Systems
OBJECTIVE OF TEST	Measure Efficiency
DURATION	4 HR
BOILER MAKE & TYPE	Bigelow KS 20
RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A
PULVERIZER, TYPE & SIZE	N/A
BURNER, SIZE(No)	116-82 (2)
FUEL USED	Oil
MINE	N/A
COUNTY	N/A
STATE	N/A
SIZE AS FIRED	N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	98.5
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	323.8
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP ENTERING (BOILER)	F	214.8
9	STEAM QUALITY % MOISTURE	%	0.49
10	AIR TEMP AROUND BOILER (AMBIENT)	F	85
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	82.9
12	TEMPERATURE OF FUEL	F	120.1
13	GAS TEMP. LEAVING (Boiler)	F	584.3
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	297.2
16	ENTHALPY OF (SATURATED STM.	Btu/lb	1182.5
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	182.8
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	999.7
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8301
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	16.5

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	29574.7
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	2158.1
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	39165.9
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	29565.6

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	12.7
33	O_2	% VOL	4.6
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.7
36	EXCESS AIR	%	26.1

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP ASTM METHOD	N/A

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9206
53	VISCOSITY AT SSU* BURNER	122
44	TOTAL HYDROGEN % wt	12.20
41	Btu per lb	18148

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	83.01
44	HYDROGEN	12.20
45	OXYGEN	4.21
46	NITROGEN	0.17
47	SULPHUR	0.40
40	ASH	0.013
37	MOISTURE	5.3
	TOTAL	

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	75.5

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1982.5	10.9
66	HEAT LOSS DUE TO MOISTURE IN FUEL	67.7	0.37
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1402.2	7.7
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	0.9
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		22.9
72	EFFICIENCY = (100 – Item 71)		77.1

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series: Pre Long Term Emulsified Oil	TEST NO. 6	BOILER NO. 3	DATE 6/24/81
OWNER OF PLANT U.S. Coast Guard	LOCATION New London, CT		
TEST CONDUCTED BY Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 4 HR	
BOILER MAKE & TYPE Bigelow KS 20	RATED CAPACITY 28,500 lbs/hr		
STOKER TYPE & SIZE N/A			
PULVERIZER, TYPE & SIZE N/A	BURNER, SIZE (No) 116-82 (2)		
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A — SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	97.9
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	323.4
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	218.3
9	STEAM QUALITY % MOISTURE	%	0.48
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	89
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	81.7
12	TEMPERATURE OF FUEL	F	120.5
13	GAS TEMP. LEAVING (Boiler)	F	548.9
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	296.7
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1182.4
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	186.3
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS./LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	996.1
21	HEAT ABS./LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8301
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	16.1

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	27542.1
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1943.1
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	35263.5
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	27436.0

FLUE GAS ANAL. (BOILER)(ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	13.0
33	O_2	% VOL	4.0
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	83.0
36	EXCESS AIR	%	21.9

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9206
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	120
40	ASH	N/A	44	TOTAL HYDROGEN % wt	12.20
	TOTAL		41	Btu per lb	18148
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP.* ASTM METHOD	N/A		GAS	% VOL

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS				
			54	CO	N/A
43	CARBON	83.01	55	CH_4 METHANE	N/A
44	HYDROGEN	12.20	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	4.21	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.17	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.40	59	H_2S	N/A
40	ASH	0.013	60	CO_2	N/A
37	MOISTURE	5.3	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	

	COAL PULVERIZATION				
				TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A
64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29			77.8

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1806.1	10.0
66	HEAT LOSS DUE TO MOISTURE IN FUEL	66.9	0.37
67	HEAT LOSS DUE TO H_2O FROM COMB. OF H_2	1385.4	7.6
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	0.9
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		21.9
72	EFFICIENCY = (100 – Item 71)		78.1

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series: Pre Long Term Emulsified Oil	TEST NO 7	BOILER NO. 3	DATE 6/25/81
OWNER OF PLANT U.S. Coast Guard	LOCATION New London, CT		
TEST CONDUCTED BY Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 4 HR	
BOILER MAKE & TYPE Bigelow KS 20	RATED CAPACITY 28,500 lbs/hr		
STOKER TYPE & SIZE N/A			
PULVERIZER, TYPE & SIZE N/A	BURNER, SIZE (No) 116-82 (2)		
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A — SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	98.0
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	323.5
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	214.9
9	STEAM QUALITY % MOISTURE	%	0.40
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	84
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	79.4
12	TEMPERATURE OF FUEL	F	119.9
13	GAS TEMP. LEAVING (Boiler)	F	558.4
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	296.8
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1183.2
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	182.9
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	1000.3
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8301
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	16.1
	HOURLY QUANTITIES		
26	ACTUAL WATER EVAPORATED	lb/hr	27576.8
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	2005.2
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	36389.6
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	27584.9
	FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET		
32	CO_2	% VOL	13.0
33	O_2	% VOL	4.1
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.9
36	EXCESS AIR	%	22.6

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9206
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	130
40	ASH	N/A	44	TOTAL HYDROGEN % wt	12.20
	TOTAL		41	Btu per lb	18148
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP ASTM METHOD	N/A		GAS	% VOL
	COAL OR OIL AS FIRED ULTIMATE ANALYSIS		54	CO	N/A
43	CARBON	83.01	55	CH_4 METHANE	N/A
44	HYDROGEN	12.20	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	4.21	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.17	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.40	59	H_2S	N/A
40	ASH	0.013	60	CO_2	N/A
37	MOISTURE	5.3	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	
	COAL PULVERIZATION			TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A
64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29			75.8

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1852.0	10.2
66	HEAT LOSS DUE TO MOISTURE IN FUEL	67.2	0.37
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1392.8	7.7
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	0.9
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		22.2
72	EFFICIENCY = (100 – Item 71)		77.8

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

·UMMARY SHEET

PTC 4.1-a (1964)

Test Series:	Pre Long Term Emulsified Oil	TEST NO 8	BOILER NO. 3	DATE 6/25/81	
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT		
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST	Measure Efficiency	DURATION	4 HR
BOILER MAKE & TYPE	Bigelow KS 20	RATED CAPACITY	28,500 lbs/hr		
STOKER TYPE & SIZE	N/A				
PULVERIZER, TYPE & SIZE	N/A	BURNER, SIZE (No)	116-82 (2)		
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A	SIZE AS FIRED N/A	

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	98.8
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	324.2
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R. H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	217.5
9	STEAM QUALITY % MOISTURE	%	0.44
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	84
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	79.2
12	TEMPERATURE OF FUEL	F	120.4
13	GAS TEMP. LEAVING (Boiler)	F	536.2
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	297.4
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1183.0
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	185.5
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	997.6
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8301
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	16.5

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	24706.2
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1763.9
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	32011.6
30	HEAT OUTPUT IN BLOW DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	24645.8

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	12.7
33	O_2	% VOL	4.6
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.7
36	EXCESS AIR	%	26.1

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9206
53	VISCOSITY AT SSU* BURNER	122
44	TOTAL HYDROGEN % wt	12.20
41	Btu per lb	18148

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	83.01
44	HYDROGEN	12.20
45	OXYGEN	4.21
46	NITROGEN	0.17
47	SULPHUR	0.40
40	ASH	0.013
37	MOISTURE	5.3
	TOTAL	

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	77.0

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1807.0	10.0
66	HEAT LOSS DUE TO MOISTURE IN FUEL	66.7	0.37
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1381.6	7.6
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	1.0
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		22.0
72	EFFICIENCY = (100 – Item 71)		78.0

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Pre Long Term Emulsified Oil	TEST NO	9	BOILER NO. 3	DATE 6/26/81
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT		
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST	Measure Efficiency	DURATION	4 HR
BOILER MAKE & TYPE	Bigelow KS 20			RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A				
PULVERIZER, TYPE & SIZE	N/A			BURNER, SIZE(No)	116-82 (2)
FUEL USED	Oil	MINE N/A	COUNTY N/A	STATE N/A	SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	97.3
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	324.1
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	216.7
9	STEAM QUALITY % MOISTURE	%	0.44
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	84
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	76.9
12	TEMPERATURE OF FUEL	F	120.8
13	GAS TEMP. LEAVING (Boiler)	F	413.0
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	296.3
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1182.7
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	184.7
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	998.0
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8301
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	17.8

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	13215.0
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	944.0
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	17132.2
30	HEAT OUTPUT IN BLOW DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	13188.9

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	11.7
33	O_2	% VOL	5.4
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.9
36	EXCESS AIR	%	32.0

FUEL DATA

No.	COAL AS FIRED PROX. ANALYSIS	% wt	No.	OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9206
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	125
40	ASH	N/A	44	TOTAL HYDROGEN % wt	12.20
	TOTAL		41	Btu per lb	18148
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP.* ASTM METHOD	N/A		GAS	% VOL

No.	COAL OR OIL AS FIRED ULTIMATE ANALYSIS		No.	GAS	% VOL
			54	CO	N/A
43	CARBON	83.01	55	CH_4 METHANE	N/A
44	HYDROGEN	12.20	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	4.21	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.17	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.40	59	H_2S	N/A
40	ASH	0.013	60	CO_2	N/A
37	MOISTURE	5.3	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	
				TOTAL HYDROGEN % wt	N/A

No.	COAL PULVERIZATION		No.		
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A
64	INPUT-OUTPUT EFFICIENCY OF UNIT %			ITEM 31 × 100 / ITEM 29	77.0

No.	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1436.3	7.9
66	HEAT LOSS DUE TO MOISTURE IN FUEL	63.8	0.35
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1321.0	7.3
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	1.9
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		20.5
72	EFFICIENCY = (100 – Item 71)		79.5

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Pre Long Term Emulsified Oil	TEST NO 10	BOILER NO. 3	DATE 6/29/81	
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT		
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST	Measure Efficiency	DURATION	4 HR
BOILER MAKE & TYPE	Bigelow KS 20	RATED CAPACITY	28,500 lbs/hr		
STOKER TYPE & SIZE	N/A				
PULVERIZER, TYPE & SIZE	N/A	BURNER, SIZE(No)	116-82 (2)		
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A	SIZE AS FIRED N/A	

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	97.9
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	324.1
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	221.7
9	STEAM QUALITY % MOISTURE	%	0.42
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	89
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	85.3
12	TEMPERATURE OF FUEL	F	121.0
13	GAS TEMP. LEAVING (Boiler)	F	443.6
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	296.7
16	ENTHALPY OF (SATURATED' STM.	Btu/lb	1183.0
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	189.7
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	993.4
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8301
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	17.4

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	16324.0
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1133.4
29	TOTAL HEAT INPUT (Item 28 x Item 41) / 1000	kB/hr	20568.2
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 x Item 20) + (Item 27 x Item 21) + Item 30 / 1000	kB/hr	16215.5

FLUE GAS ANAL. (BOILER)(ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	12.0
33	O_2	% VOL	5.2
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.8
36	EXCESS AIR	%	30.5

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	83.01
44	HYDROGEN	12.20
45	OXYGEN	4.21
46	NITROGEN	0.17
47	SULPHUR	0.40
40	ASH	0.013
37	MOISTURE	5.3
	TOTAL	

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9206
53	VISCOSITY AT SSU* BURNER	131
44	TOTAL HYDROGEN % wt	12.20
41	Btu per lb	18148

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT % (ITEM 31 x 100 / ITEM 29)	78.8

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1494.9	8.2
66	HEAT LOSS DUE TO MOISTURE IN FUEL	64.1	0.40
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1327.4	7.3
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	----	----
69	HEAT LOSS DUE TO RADIATION	----	1.6
70	UNMEASURED LOSSES	----	3.0
71	TOTAL		20.5
72	EFFICIENCY = (100 – Item 71)		79.5

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Pre Long Term Emulsified Oil	TEST NO	11	BOILER NO. 3	DATE 6/29/81
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT		
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST	Measure Efficiency	DURATION	4 HR
BOILER MAKE & TYPE	Bigelow KS 20			RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A				
PULVERIZER, TYPE & SIZE	N/A			BURNER, SIZE(No)	116-82 (2)
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A	SIZE AS FIRED	N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	99.3
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	324.7
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	221.4
9	STEAM QUALITY % MOISTURE	%	0.44
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	92
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature)	F	85.4
12	TEMPERATURE OF FUEL	F	120.3
13	GAS TEMP. LEAVING (Boiler)	F	480.5
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	297.8
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1183.1
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	189.4
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 - ITEM 17)	Btu/lb	993.7
21	HEAT ABS/LB R.H. STEAM (ITEM 19 - ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8301
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	17.5

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	18871.2
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1312.2
29	TOTAL HEAT INPUT (Item 28 x Item 41) / 1000	kB/hr	23813.1
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	18753.2

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	11.9
33	O_2	% VOL	5.4
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.7
36	EXCESS AIR	%	32.1

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9206
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	131
40	ASH	N/A	44	TOTAL HYDROGEN % wt	12.20
	TOTAL		41	Btu per lb	18148
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP.* ASTM METHOD	N/A		GAS	% VOL
	COAL OR OIL AS FIRED ULTIMATE ANALYSIS		54	CO	N/A
43	CARBON	83.01	55	CH_4 METHANE	N/A
44	HYDROGEN	12.20	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	4.21	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.17	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.40	59	H_2S	N/A
40	ASH	0.013	60	CO_2	N/A
37	MOISTURE	5.3	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	
	COAL PULVERIZATION			TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A
64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29			78.8

HEAT LOSS EFFICIENCY

		Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1661.9	9.2
66	HEAT LOSS DUE TO MOISTURE IN FUEL	65.0	0.40
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1346.3	7.4
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	1.4
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		21.3
72	EFFICIENCY = (100 - Item 71)		78.7

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series: Pre Long Term Emulsified Oil TEST NO 12 BOILER NO. 3 DATE 6/29/81

OWNER OF PLANT U.S. Coast Guard LOCATION New London, CT

TEST CONDUCTED BY Seaworthy Engine Systems OBJECTIVE OF TEST Measure Efficiency DURATION 4 HR

BOILER MAKE & TYPE Bigelow KS 20 RATED CAPACITY 28,500 lbs/hr

STOKER TYPE & SIZE N/A

PULVERIZER, TYPE & SIZE N/A BURNER, SIZE(No) 116-82 (2)

FUEL USED Oil MINE N/A COUNTY N/A STATE N/A SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	100.0
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	325.1
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	220.7
9	STEAM QUALITY % MOISTURE	%	0.41
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	87
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	78.3
12	TEMPERATURE OF FUEL	F	119.9
13	GAS TEMP. LEAVING (Boiler)	F	504.6
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	298.4
16	ENTHALPY OF (SATURATED STM.	Btu/lb	1183.5
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	188.7
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	994.8
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8301
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	16.8

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	21201.2
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1478.8
29	TOTAL HEAT INPUT (Item 28 x Item 41) / 1000	kB/hr	26838.0
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT ((Item 26 × Item 20) + (Item 27 × Item 21) + Item 30) / 1000	kB/hr	21091.4

FLUE GAS ANAL. (BOILER)(ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	12.4
33	O_2	% VOL	4.8
34	CO	% VOL	0.01
35	N_2 (BY DIFFERENCE)	% VOL	82.8
36	EXCESS AIR	%	27.5

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	83.01
44	HYDROGEN	12.20
45	OXYGEN	4.21
46	NITROGEN	0.17
47	SULPHUR	0.40
40	ASH	0.013
37	MOISTURE	5.3
	TOTAL	

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9206
53	VISCOSITY AT SSU* BURNER	137
44	TOTAL HYDROGEN % wt	12.20
41	Btu per lb	18148

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	78.6

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1724.0	9.5
66	HEAT LOSS DUE TO MOISTURE IN FUEL	66.0	0.40
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1366.4	7.5
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	1.2
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		21.6
72	EFFICIENCY = (100 – Item 71)		78.4

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a(1964)

Test Series:	Post Long Term Emulsified Oil	TEST NO 1	BOILER NO. 3 DATE 3/22/82
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 4 HR
BOILER MAKE & TYPE	Bigelow KS 20	RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A		
PULVERIZER, TYPE & SIZE	N/A	BURNER, SIZE(No)	116-82 (2)
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	99.1
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	325.3
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	215.9
9	STEAM QUALITY % MOISTURE	%	0.69
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	73
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	73.3
12	TEMPERATURE OF FUEL	F	118.8
13	GAS TEMP. LEAVING (Boiler)	F	599.8
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	297.7
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1180.9
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	183.9
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	997.0
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8077
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	15.6

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	29188.6
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	2166.0
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	38685.0
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	29099.9

FLUE GAS ANAL. (BOILER)(ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	13.1
33	O_2	% VOL	3.9
34	CO	% VOL	0.0
35	N_2 (BY DIFFERENCE)	% VOL	83.0
36	EXCESS AIR	%	21.2

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9254
53	VISCOSITY AT SSU* BURNER	300
44	TOTAL HYDROGEN % wt	11.19
41	Btu per lb	17860

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	80.77
44	HYDROGEN	11.19
45	OXYGEN	1.04
46	NITROGEN	0.10
47	SULPHUR	0.49
40	ASH	0.013
37	MOISTURE	6.4
	TOTAL	

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

COAL PULVERIZATION

48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	75.2

HEAT LOSS EFFICIENCY

		Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1968.5	11.0
66	HEAT LOSS DUE TO MOISTURE IN FUEL	82.8	0.46
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1303.1	7.3
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	0.89
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		22.7
72	EFFICIENCY = (100 – Item 71)		77.3

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series: Post Long Term Emulsified Oil	TEST NO 2	BOILER NO. 3	DATE 3/23/82
OWNER OF PLANT U.S. Coast Guard	LOCATION New London, CT		
TEST CONDUCTED BY Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 4 HR	
BOILER MAKE & TYPE Bigelow KS 20	RATED CAPACITY 28,500 lbs/hr		
STOKER TYPE & SIZE N/A			
PULVERIZER, TYPE & SIZE N/A	BURNER, SIZE (No) 116-82 (2)		
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A · SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	99.3
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	325.2
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R. H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	220.3
9	STEAM QUALITY % MOISTURE	%	0.80
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	74
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	77.7
12	TEMPERATURE OF FUEL	F	120.6
13	GAS TEMP. LEAVING (Boiler)	F	594.2
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	297.8
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1179.9
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	188.3
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	991.6
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8077
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	15.7

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	28467.2
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	2110.6
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	37694.4
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT [(Item 26 × Item 20) + (Item 27 × Item 21) + Item 30] / 1000	kB/hr	28227.4

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	13.0
33	O_2	% VOL	4.2
34	CO	% VOL	0.0
35	N_2 (BY DIFFERENCE)	% VOL	82.8
36	EXCESS AIR	%	23.3

FUEL DATA

No.	COAL AS FIRED PROX. ANALYSIS	% wt	No.	OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9254
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	282
40	ASH	N/A	44	TOTAL HYDROGEN % wt	11.19
	TOTAL		41	Btu per lb	17860
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP.* ASTM METHOD	N/A		GAS	% VOL

No.	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	% wt	No.	GAS	% VOL
			54	CO	N/A
43	CARBON	80.77	55	CH_4 METHANE	N/A
44	HYDROGEN	11.19	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	1.04	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.10	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.49	59	H_2S	N/A
40	ASH	0.013	60	CO_2	N/A
37	MOISTURE	6.4	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	

No.	COAL PULVERIZATION		No.		
				TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A
64	INPUT-OUTPUT EFFICIENCY OF UNIT % (ITEM 31 × 100 / ITEM 29)				77.9

No.	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1945.7	10.9
66	HEAT LOSS DUE TO MOISTURE IN FUEL	82.4	0.46
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1296.0	7.3
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	0.92
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		22.5
72	EFFICIENCY = (100 – Item 71)		77.5

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Post Long Term Emulsified Oil
TEST NO	3
BOILER NO.	3
DATE	3/23/82
OWNER OF PLANT	U.S. Coast Guard
LOCATION	New London, CT
TEST CONDUCTED BY	Seaworthy Engine Systems
OBJECTIVE OF TEST	Measure Efficiency
DURATION	4 HR
BOILER MAKE & TYPE	Bigelow KS 20
RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A
PULVERIZER, TYPE & SIZE	N/A
BURNER, SIZE (No)	116-82 (2)
FUEL USED	Oil
MINE	N/A
COUNTY	N/A
STATE	N/A
SIZE AS FIRED	N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	98.5
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	324.8
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	221.3
9	STEAM QUALITY % MOISTURE	%	0.69
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	78
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	80.5
12	TEMPERATURE OF FUEL	F	120.6
13	GAS TEMP. LEAVING (Boiler)	F	562.2
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	297.2
16	ENTHALPY OF (SATURATED STM.	Btu/lb	1180.8
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	189.3
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	991.5
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8077
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	14.4

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	27548.1
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1991.5
29	TOTAL HEAT INPUT (Item 28 x Item 41) / 1000	kB/hr	35568.5
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 x Item 20) + (Item 27 x Item 21) + Item 30 / 1000	kB/hr	27312.8

FLUE GAS ANAL. (BOILER)(ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	14.2
33	O_2	% VOL	2.8
34	CO	% VOL	0.0
35	N_2 (BY DIFFERENCE)	% VOL	83.0
36	EXCESS AIR	%	14.4

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9254
53	VISCOSITY AT SSU* BURNER	282
44	TOTAL HYDROGEN % wt	11.19
41	Btu per lb	17860

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	80.77
44	HYDROGEN	11.19
45	OXYGEN	1.04
46	NITROGEN	0.10
47	SULPHUR	0.49
40	ASH	0.013
37	MOISTURE	6.4
	TOTAL	

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT % (ITEM 31 x 100 / ITEM 29)	76.8

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1668.7	9.3
66	HEAT LOSS DUE TO MOISTURE IN FUEL	81.2	0.45
67	HEAT LOSS DUE TO H_2O FROM COMB. OF H_2	1278.2	7.2
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	0.95
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		20.9
72	EFFICIENCY = (100 – Item 71)		79.1

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Post Long Term Emulsified Oil	TEST NO.	4	BOILER NO.	3	DATE	3/24/82
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT				
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST	Measure Efficiency	DURATION	4 HR		
BOILER MAKE & TYPE	Bigelow KS 20	RATED CAPACITY	28,500 lbs/hr				
STOKER TYPE & SIZE	N/A						
PULVERIZER, TYPE & SIZE	N/A	BURNER, SIZE (No)	116-82 (2)				
FUEL USED	Oil	MINE	N/A	COUNTY	N/A	STATE	N/A
SIZE AS FIRED	N/A						

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	95.5
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	324.2
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R. H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	217.9
9	STEAM QUALITY % MOISTURE	%	0.39
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	74
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	74.0
12	TEMPERATURE OF FUEL	F	121.0
13	GAS TEMP. LEAVING (Boiler)	F	349.8
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	294.8
16	ENTHALPY OF (SATURATED STM.	Btu/lb	1182.9
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	185.9
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	997.0
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8077
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	15.9

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	9880.2
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	681.4
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	12170.5
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	9850.2

FLUE GAS ANAL. (BOILER)(ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	12.8
33	O_2	% VOL	4.4
34	CO	% VOL	0.0
35	N_2 (BY DIFFERENCE)	% VOL	82.8
36	EXCESS AIR	%	24.7

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	80.77
44	HYDROGEN	11.19
45	OXYGEN	1.04
46	NITROGEN	0.10
47	SULPHUR	0.49
40	ASH	0.013
37	MOISTURE	6.4
	TOTAL	

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9254
53	VISCOSITY AT SSU* BURNER	273
44	TOTAL HYDROGEN % wt	11.19
41	Btu per lb	17860

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	80.9

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1054.4	5.9
66	HEAT LOSS DUE TO MOISTURE IN FUEL	75.3	0.42
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1184.8	6.6
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	2.55
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		18.5
72	EFFICIENCY = (100 – Item 71)		81.5

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series: Post Long Term Emulsified Oil	TEST NO 5	BOILER NO. 3	DATE 3/24/82
OWNER OF PLANT: U.S. Coast Guard		LOCATION: New London, CT	
TEST CONDUCTED BY: Seaworthy Engine Systems	OBJECTIVE OF TEST: Measure Efficiency		DURATION 4 HR
BOILER MAKE & TYPE: Bigelow KS 20		RATED CAPACITY 28,500 lbs/hr	
STOKER TYPE & SIZE: N/A			
PULVERIZER, TYPE & SIZE: N/A		BURNER, SIZE (No) 116-82 (2)	
FUEL USED: Oil	MINE: N/A	COUNTY: N/A	STATE: N/A / SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	96.2
2	STEAM PRESSURE AT S.H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R.H. INLET	psia	N/A
4	STEAM PRESSURE AT R.H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	324.6
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	218.4
9	STEAM QUALITY % MOISTURE	%	0.40
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	77
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	74.9
12	TEMPERATURE OF FUEL	F	118.5
13	GAS TEMP. LEAVING (Boiler)	F	349.6
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	295.4
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1182.9
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	186.4
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R.H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	996.5
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8077
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	15.9

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	9724.7
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	671.7
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	11997.4
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	9690.3

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	12.8
33	O_2	% VOL	4.5
34	CO	% VOL	0.0
35	N_2 (BY DIFFERENCE)	% VOL	82.7
36	EXCESS AIR	%	25.4

FUEL DATA

No.	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

No.	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9254
53	VISCOSITY AT SSU* BURNER	293
44	TOTAL HYDROGEN % wt	11.19
41	Btu per lb	17860

No.	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	80.77
44	HYDROGEN	11.19
45	OXYGEN	1.04
46	NITROGEN	0.10
47	SULPHUR	0.49
40	ASH	0.013
37	MOISTURE	6.4
	TOTAL	

No.	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

No.	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	80.8

No.	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1050.3	5.9
66	HEAT LOSS DUE TO MOISTURE IN FUEL	75.2	0.42
67	HEAT LOSS DUE TO H_2O FROM COMB. OF H_2	1183.8	6.6
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	2.59
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		18.5
72	EFFICIENCY = (100 – Item 71)		81.5

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Post Long Term Emulsified Oil	TEST NO 6	BOILER NO. 3 DATE 3/25/82
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 4 HR
BOILER MAKE & TYPE	Bigelow KS 20	RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A		
PULVERIZER, TYPE & SIZE	N/A	BURNER, SIZE(No)	116-82 (2)
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	95.6
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	324.3
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	218.7
9	STEAM QUALITY % MOISTURE	%	0.34
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	73
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	73.9
12	TEMPERATURE OF FUEL	F	124.3
13	GAS TEMP. LEAVING (Boiler)	F	352.1
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	294.9
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1183.3
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	186.7
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	996.6
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8077
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	15.8

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	9873.1
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	684.5
29	TOTAL HEAT INPUT (Item 28 x Item 41) / 1000	kB/hr	12225.7
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	9839.4

FLUE GAS ANAL. (BOILER)(ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	12.9
33	O_2	% VOL	4.3
34	CO	% VOL	0.0
35	N_2 (BY DIFFERENCE)	% VOL	82.8
36	EXCESS AIR	%	24.0

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP ASTM METHOD	N/A

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9254
53	VISCOSITY AT SSU* BURNER	260
44	TOTAL HYDROGEN % wt	11.19
41	Btu per lb	17860

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	80.77
44	HYDROGEN	11.19
45	OXYGEN	1.04
46	NITROGEN	0.10
47	SULPHUR	0.49
40	ASH	0.013
37	MOISTURE	6.4
	TOTAL	

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT % (ITEM 31 × 100 / ITEM 29)	80.5

HEAT LOSS EFFICIENCY

		Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1055.7	5.9
66	HEAT LOSS DUE TO MOISTURE IN FUEL	75.4	0.42
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1186.0	6.6
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	2.55
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		18.5
72	EFFICIENCY = (100 – Item 71)		81.5

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series: Post Long Term Emulsified Oil	TEST NO 7R	BOILER NO. 3	DATE 3/26/82
OWNER OF PLANT U.S. Coast Guard		LOCATION New London, CT	
TEST CONDUCTED BY Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency		DURATION 4 HR
BOILER MAKE & TYPE Bigelow KS 20			RATED CAPACITY 28,500 lbs/hr
STOKER TYPE & SIZE N/A			
PULVERIZER, TYPE & SIZE N/A			BURNER, SIZE(No)116-82 (1)
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	95.8
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	324.3
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R. H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	218.8
9	STEAM QUALITY % MOISTURE	%	0.27
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	76
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	76.3
12	TEMPERATURE OF FUEL	F	118.5
13	GAS TEMP. LEAVING (Boiler)	F	323.6
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	295.1
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1183.9
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	186.8
18	ENTHALPY OF REHEATED STEAM R. H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	997.1
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8077
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	17.2

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	6214.3
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	420.0
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	7500.3
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	6196.5

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	11.8
33	O_2	% VOL	5.5
34	CO	% VOL	0.0
35	N_2 (BY DIFFERENCE)	% VOL	82.7
36	EXCESS AIR	%	33.0

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	80.77
44	HYDROGEN	11.19
45	OXYGEN	1.04
46	NITROGEN	0.10
47	SULPHUR	0.49
40	ASH	0.013
37	MOISTURE	6.4
	TOTAL	

	OIL	
51	FLASH POINT F*	No Da[ta]
52	Sp. Gravity	0.925[…]
53	VISCOSITY AT SSU* BURNER	295
44	TOTAL HYDROGEN % wt	11.1[…]
41	Btu per lb	1786[…]

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
44	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/[A]
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

COAL PULVERIZATION

48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT % — ITEM 31 × 100 / ITEM 29	82.[…]

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A F FUEL
65	HEAT LOSS DUE TO DRY GAS	1021.6	5.7
66	HEAT LOSS DUE TO MOISTURE IN FUEL	74.4	0.4[…]
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1170.2	6.6
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	4.0[…]
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		19.[…]
72	EFFICIENCY – (100 – Item 71)		80.[…]

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Post Long Term Emulsified Oil	TEST NO	8	BOILER NO. 3	DATE 3/26/82
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT		
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST	Measure Efficiency	DURATION	4 HR
BOILER MAKE & TYPE	Bigelow KS 20			RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A				
PULVERIZER, TYPE & SIZE	N/A			BURNER, SIZE(No)	116-82 (2)
FUEL USED	Oil	MINE N/A	COUNTY N/A	STATE N/A	SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	97.0
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	325.0
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	217.1
9	STEAM QUALITY % MOISTURE	%	0.42
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	74
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	75.5
12	TEMPERATURE OF FUEL	F	118.2
13	GAS TEMP. LEAVING (Boiler)	F	394.5
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	296.0
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1182.8
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	185.1
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	997.7
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8077
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	16.2

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	11694.7
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	840.8
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	15015.7
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	11668.0

FLUE GAS ANAL. (BOILER) (ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	12.6
33	O_2	% VOL	4.4
34	CO	% VOL	0.0
35	N_2 (BY DIFFERENCE)	% VOL	83.0
36	EXCESS AIR	%	24.6

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	80.77
44	HYDROGEN	11.19
45	OXYGEN	1.04
46	NITROGEN	0.10
47	SULPHUR	0.49
40	ASH	0.013
37	MOISTURE	6.4
	TOTAL	

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9254
53	VISCOSITY AT SSU* BURNER	298
44	TOTAL HYDROGEN % wt	11.19
41	Btu per lb	17860

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT % (ITEM 31 × 100 / ITEM 29)	77.0

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1237.5	6.9
66	HEAT LOSS DUE TO MOISTURE IN FUEL	76.5	0.43
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1204.3	6.7
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	2.16
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		19.3
72	EFFICIENCY = (100 – Item 71)		80.7

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Post Long Term Emulsified Oil
TEST NO	9
BOILER NO.	3
DATE	3/29/82
OWNER OF PLANT	U.S. Coast Guard
LOCATION	New London, CT
TEST CONDUCTED BY	Seaworthy Engine Systems
OBJECTIVE OF TEST	Measure Efficiency
DURATION	4 HR
BOILER MAKE & TYPE	Bigelow KS 20
RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A
PULVERIZER, TYPE & SIZE	N/A
BURNER, SIZE(No)	116-82 (2
FUEL USED	Oil
MINE	N/A
COUNTY	N/A
STATE	N/A
SIZE AS FIRED	N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	98.2
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	325.7
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	218.9
9	STEAM QUALITY % MOISTURE	%	0.26
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	74
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	77.6
12	TEMPERATURE OF FUEL	F	119.4
13	GAS TEMP. LEAVING (Boiler)	F	443.9
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	297.0
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1184.5
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	186.9
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	997.6
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8077
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	16.0

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	15733.5
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1136.0
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	20289.0
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	15696.5

FLUE GAS ANAL. (BOILER)(ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	12.7
33	O_2	% VOL	4.2
34	CO	% VOL	0.0
35	N_2 (BY DIFFERENCE)	% VOL	83.1
36	EXCESS AIR	%	23.2

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	80.77
44	HYDROGEN	11.19
45	OXYGEN	1.04
46	NITROGEN	0.10
47	SULPHUR	0.49
40	ASH	0.013
37	MOISTURE	6.4
	TOTAL	

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

	OIL	
51	FLASH POINT F*	No Da
52	Sp. Gravity *	0.925
53	VISCOSITY AT SSU* BURNER	288
44	TOTAL HYDROGEN % wt	11.1
41	Btu per lb	1786

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	77.4

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1410.2	7.9
66	HEAT LOSS DUE TO MOISTURE IN FUEL	77.9	0.44
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1225.5	6.9
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	1.62
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		19.8
72	EFFICIENCY – (100 – Item 71)		80.2

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Post Long Term Emulsified Oil	TEST NO	10	BOILER NO. 3	DATE 3/29/82
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT		
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST	Measure Efficiency	DURATION	4 HR
BOILER MAKE & TYPE	Bigelow KS 20	RATED CAPACITY	28,500 lbs/hr		
STOKER TYPE & SIZE	N/A				
PULVERIZER, TYPE & SIZE	N/A	BURNER, SIZE(No)	116-82 (2)		
FUEL USED	Oil	MINE N/A	COUNTY N/A	STATE N/A	SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	98.2
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	325.6
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	217.8
9	STEAM QUALITY % MOISTURE	%	0.28
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	79
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	80.7
12	TEMPERATURE OF FUEL	F	119.4
13	GAS TEMP. LEAVING (Boiler)	F	462.4
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	297.0
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1184.3
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	185.8
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	998.5
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8077
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	15.7

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	17944.1
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1282.6
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	22906.4
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	17917.4

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	13.0
33	O_2	% VOL	3.8
34	CO	% VOL	0.0
35	N_2 (BY DIFFERENCE)	% VOL	83.2
36	EXCESS AIR	%	20.5

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9254
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	290
40	ASH	N/A	44	TOTAL HYDROGEN % wt	11.19
	TOTAL		41	Btu per lb	17860
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP.* ASTM METHOD	N/A		GAS	% VOL

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS				
			54	CO	N/A
43	CARBON	80.77	55	CH_4 METHANE	N/A
44	HYDROGEN	11.19	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	1.04	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.10	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.49	59	H_2S	N/A
40	ASH	0.013	60	CO_2	N/A
37	MOISTURE	6.4	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	
	COAL PULVERIZATION			TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT % (ITEM 31 × 100 / ITEM 29)	78.2

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1437.1	8.0
66	HEAT LOSS DUE TO MOISTURE IN FUEL	78.2	0.44
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1231.0	6.9
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	----	----
69	HEAT LOSS DUE TO RADIATION	----	1.43
70	UNMEASURED LOSSES	----	3.0
71	TOTAL		19.8
72	EFFICIENCY = (100 – Item 71)		80.2

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series: Post Long Term Emulsified Oil TEST NO 11 BOILER NO. 3 DATE 3/30/82

OWNER OF PLANT: U.S. Coast Guard LOCATION: New London, CT

TEST CONDUCTED BY: Seaworthy Engine Systems OBJECTIVE OF TEST: Measure Efficiency DURATION: 4 HR

BOILER MAKE & TYPE: Bigelow KS 20 RATED CAPACITY: 28,500 lbs/hr

STOKER TYPE & SIZE: N/A

PULVERIZER, TYPE & SIZE: N/A BURNER, SIZE(No) 116-82 (2)

FUEL USED: Oil MINE: N/A COUNTY: N/A STATE: N/A SIZE AS FIRED: N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	98.9
2	STEAM PRESSURE AT S.H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R.H. INLET	psia	N/A
4	STEAM PRESSURE AT R.H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	326.0
6	STEAM TEMPERATURE AT R.H. INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	216.8
9	STEAM QUALITY % MOISTURE	%	0.39
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	75
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	76.9
12	TEMPERATURE OF FUEL	F	119.3
13	GAS TEMP. LEAVING (Boiler)	F	512.1
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	297.5
16	ENTHALPY OF (SATURATED) STM	Btu/lb	1183.5
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	184.8
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R.H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	998.7
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8077
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	15.5

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	21696.2
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1590.5
29	TOTAL HEAT INPUT (Item 28 x Item 41) / 1000	kB/hr	28405.8
30	HEAT OUTPUT IN BLOW DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 x Item 20) + (Item 27 x Item 21) + Item 30 / 1000	kB/hr	21667.4

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	13.2
33	O_2	% VOL	3.8
34	CO	% VOL	0.0
35	N_2 (BY DIFFERENCE)	% VOL	83.0
36	EXCESS AIR	%	20.0

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp Gravity	0.9254
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU BURNER	290
40	ASH	N/A	44	TOTAL HYDROGEN % wt	11.19
	TOTAL		41	Btu per lb	17860
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP.* ASTM METHOD	N/A		GAS	% VOL

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS				
			54	CO	N/A
43	CARBON	80.77	55	CH_4 METHANE	N/A
44	HYDROGEN	11.19	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	1.04	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.10	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.49	59	H_2S	N/A
40	ASH	0.013	60	CO_2	N/A
37	MOISTURE	6.4	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	
				TOTAL HYDROGEN % wt	N/A

	COAL PULVERIZATION				
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM PRESS	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 / ITEM 29 × 100	76.3

	HEAT LOSS EFFICIENCY	Btu/lb A.F. FUEL	% of A.F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1615.4	9.0
66	HEAT LOSS DUE TO MOISTURE IN FUEL	8[illegible].6	0.45
67	HEAT LOSS DUE TO H_2O FROM COMB. OF H_2	1258.2	7.[illegible]
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	--
69	HEAT LOSS DUE TO RADIATION	---	[illegible]
70	UNMEASURED LOSSES	---	3.[illegible]
71	TOTAL		[illegible]
72	EFFICIENCY = (100 – Item 71)		7[illegible].3

* Not Required for Efficiency Testing

† For Point of Measurement See Par. [illegible] PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series: Post Long Term Emulsified Oil TEST NO 12 BOILER NO. 3 DATE 3/30/82

OWNER OF PLANT U.S. Coast Guard LOCATION New London, CT

TEST CONDUCTED BY Seaworthy Engine Systems OBJECTIVE OF TEST Measure Efficiency DURATION 4 HR

BOILER MAKE & TYPE Bigelow KS 20 RATED CAPACITY 28,500 lbs/hr

STOKER TYPE & SIZE N/A

PULVERIZER, TYPE & SIZE N/A BURNER, SIZE (No) 116-82 (2)

FUEL USED Oil MINE N/A COUNTY N/A STATE N/A SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	99.6
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	326.1
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	214.8
9	STEAM QUALITY % MOISTURE	%	0.36
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	80
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	82.0
12	TEMPERATURE OF FUEL	F	119.9
13	GAS TEMP. LEAVING (Boiler)	F	547.5
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	298.1
16	ENTHALPY OF (SATURATED STM.	Btu/lb	1183.9
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	182.8
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 - ITEM 17)	Btu/lb	1001.1
21	HEAT ABS/LB R.H. STEAM (ITEM 19 - ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8077
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	15.6

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	24822.3
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1825.6
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	32605.8
30	HEAT OUTPUT IN BLOW DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	24849.4

FLUE GAS ANAL (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	13.1
33	O_2	% VOL	3.7
34	CO	% VOL	0.0
35	N_2 (BY DIFFERENCE)	% VOL	83.2
36	EXCESS AIR	%	19.9

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	80.77
44	HYDROGEN	11.19
45	OXYGEN	1.04
46	NITROGEN	0.10
47	SULPHUR	0.49
40	ASH	0.013
37	MOISTURE	6.4
	TOTAL	

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9254
53	VISCOSITY AT SSU* BURNER	285
44	TOTAL HYDROGEN % wt	11.19
41	Btu per lb	17860

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	76.2

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1739.9	9.7
66	HEAT LOSS DUE TO MOISTURE IN FUEL	80.7	0.45
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1269.8	7.1
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	1.04
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		21.3
72	EFFICIENCY = (100 - Item 71)		78.7

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Final Baseline Neat Oil	TEST NO	1	BOILER NO. 3	DATE 4/12/82
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT		
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST	Measure Efficiency	DURATION	4 HR
BOILER MAKE & TYPE	Bigelow KS 20			RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A				
PULVERIZER, TYPE & SIZE	N/A			BURNER, SIZE(No)	116-82 (2)
FUEL USED Oil	MINE N/A	COUNTY	N/A	STATE N/A	SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	96.7
2	STEAM PRESSURE AT S.H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R.H. INLET	psia	N/A
4	STEAM PRESSURE AT R.H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	324.7
6	STEAM TEMPERATURE AT R.H. INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	215.2
9	STEAM QUALITY % MOISTURE	%	0.39
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	80
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	78.9
12	TEMPERATURE OF FUEL	F	124.6
13	GAS TEMP. LEAVING (Boiler)	F	408.2
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	295.8
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1183.1
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	183.2
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R.H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 - ITEM 17)	Btu/lb	999.9
21	HEAT ABS/LB R.H. STEAM (ITEM 19 - ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8618
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	17.0

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	12302.4
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	851.0
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	16264.4
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	12301.1

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	12.8
33	O_2	% VOL	4.4
34	CO	% VOL	0.0
35	N_2 (BY DIFFERENCE)	% VOL	82.8
36	EXCESS AIR	%	24.7

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9218
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	221
40	ASH	N/A	44	TOTAL HYDROGEN % wt	12.62
	TOTAL		41	Btu per lb	19111
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP.* ASTM METHOD	N/A		GAS	% VOL
	COAL OR OIL AS FIRED ULTIMATE ANALYSIS		54	CO	N/A
43	CARBON	86.18	55	CH_4 METHANE	N/A
44	HYDROGEN	12.62	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	0.36	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.21	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.59	59	H_2S	N/A
40	ASH	0.017	60	CO_2	N/A
37	MOISTURE	0.02	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	
	COAL PULVERIZATION			TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A
64	INPUT-OUTPUT EFFICIENCY OF UNIT %			ITEM 31 × 100 / ITEM 29	75.6

	HEAT LOSS EFFICIENCY	Btu/lb A.F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1343.6	7.0
66	HEAT LOSS DUE TO MOISTURE IN FUEL	0.24	0.00
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1361.6	7.1
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	2.1
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		19.2
72	EFFICIENCY = (100 - Item 71)		80.8

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Final Baseline Neat Oil	TEST NO 2	BOILER NO. 3 DATE 4/12/82
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 4 HR
BOILER MAKE & TYPE	Bigelow KS 20	RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A		
PULVERIZER, TYPE & SIZE	N/A	BURNER, SIZE(No)	116-82 (2
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	97.1
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	324.6
6	STEAM TEMPERATURE AT R. H. INLET	F	N/A
7	STEAM TEMPERATURE AT R. H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	218.7
9	STEAM QUALITY % MOISTURE	%	0.32
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	80
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	85.3
12	TEMPERATURE OF FUEL	F	125.3
13	GAS TEMP. LEAVING (Boiler)	F	443.1
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	296.1
16	ENTHALPY OF (SATURATED) STM	Btu/lb	1183.8
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	186.7
18	ENTHALPY OF REHEATED STEAM R. H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
[illegible]	HEAT ABS LB OF STEAM (ITEM [illegible] – ITEM [illegible])	Btu/lb	997.1
[illegible]	HEAT ABS LB R. H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
[illegible]	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
[illegible]	[illegible] PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
[illegible]	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8618
[illegible]	[illegible]	[illegible]	16.9

HOURLY QUANTITIES

[illegible]	[illegible]	[illegible]	16413.6
[illegible]	[illegible]	[illegible]	N/A
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] HEAT INPUT (Item 28 × [illegible])	kB/hr	[illegible]
[illegible]	[illegible]	[illegible]	N/A
[illegible]	TOTAL HEAT [illegible]	[illegible]	[illegible]
[illegible]	[illegible] GAS [illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] (BY DIFFERENCE)	% VOL	[illegible]
[illegible]	[illegible] AIR	%	[illegible]

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	86.18
44	HYDROGEN	12.62
45	OXYGEN	0.36
46	NITROGEN	0.21
47	SULPHUR	0.59
40	ASH	0.017
37	MOISTURE	0.02
	TOTAL	

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9218
53	VISCOSITY AT SSU* BURNER	215
44	TOTAL HYDROGEN % wt	12.62
41	Btu per lb	19111

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

COAL PULVERIZATION

48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	77.[illegible]

HEAT LOSS EFFICIENCY

		Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1448.8	7.[illegible]
66	HEAT LOSS DUE TO MOISTURE IN FUEL	0.24	0.00
67	HEAT LOSS DUE TO H_2O FROM COMB. OF H_2	1372.[illegible]	7.2
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	----	----
69	HEAT LOSS DUE TO RADIATION	----	[illegible]
70	UNMEASURED LOSSES	----	[illegible]
	TOTAL		1[illegible].3
[illegible]	EFFICIENCY = (100 – Item 71)		[illegible]

* Not Required [illegible] Test [illegible]

† [illegible] of [illegible] Sec. [illegible] PTC 4.1-1964

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

SUMMARY SHEET — PTC 4.1-a (1964)

Test Series: Final Baseline Neat Oil	TEST NO 3 — BOILER NO. 3 — DATE 4/13/82
OWNER OF PLANT U.S. Coast Guard	LOCATION New London, CT
TEST CONDUCTED BY Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency — DURATION 4 HR
BOILER MAKE & TYPE Bigelow KS 20	RATED CAPACITY 28,500 lbs/hr
STOKER TYPE & SIZE N/A	
PULVERIZER, TYPE & SIZE N/A	BURNER, SIZE(No) 116-82 (1)
FUEL USED Oil — MINE N/A — COUNTY N/A	STATE N/A — SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	95.2
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	324.0
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	219.2
9	STEAM QUALITY % MOISTURE	%	0.26
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	76
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	80.2
12	TEMPERATURE OF FUEL	F	119.1
13	GAS TEMP. LEAVING (Boiler)	F	317.7
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	294.6
16	ENTHALPY OF (SATURATED) STM	Btu/lb	1183.9
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	187.2
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	996.7
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8704
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	17.7

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	6037.9
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	3[illegible]6.[illegible]
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	7515.6
30	HEAT OUTPUT IN BLOW DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	6[illegible]18.0

FLUE GAS ANAL. (BOILER) (ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	12.[illegible]
33	O_2	% VOL	[illegible]
34	CO	% VOL	0.0
35	N_2 BY DIFFERENCE	% VOL	[illegible]
36	EXCESS AIR	%	[illegible]9.1

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9377
53	VISCOSITY AT SSU* BURNER	333
44	TOTAL HYDROGEN % wt	11.75
41	Btu per lb	18943

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	87.04
44	HYDROGEN	11.75
45	OXYGEN	0.17
46	NITROGEN	0.22
47	SULPHUR	0.58
40	ASH	0.055
37	MOISTURE	0.19
	TOTAL	

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM PRESS	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	80.1

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1008.9	[illegible].3
66	HEAT LOSS DUE TO MOISTURE IN FUEL	2.2	0.0
67	HEAT LOSS DUE TO H_2O FROM COMB. OF H_2	12[illegible]	[illegible]
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	—	[illegible]
69	HEAT LOSS DUE TO RADIATION	—	[illegible]
70	UNMEASURED LOSSES	—	[illegible]
71	TOTAL		18.[illegible]
72	EFFICIENCY = (100 – Item 71)		[illegible]

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series: Final Baseline Neat Oil	TEST NO 4	BOILER NO. 3	DATE 4/13/82
OWNER OF PLANT U.S. Coast Guard		LOCATION New London, CT	
TEST CONDUCTED BY Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency		DURATION 4 HR
BOILER MAKE & TYPE Bigelow KS 20		RATED CAPACITY 28,500 lbs/hr	
STOKER TYPE & SIZE N/A			
PULVERIZER, TYPE & SIZE N/A		BURNER, SIZE (No) 116-82 (2)	
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A — SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	96.4
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	324.6
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	218.3
9	STEAM QUALITY % MOISTURE	%	0.36
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	78
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	78.4
12	TEMPERATURE OF FUEL	F	122.6
13	GAS TEMP. LEAVING (Boiler)	F	371.9
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	295.6
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1183.3
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	186.3
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	997.0
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8704
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	16.9

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	10622.4
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	716.7
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	13577.1
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	10590.4

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	13.0
33	O_2	% VOL	4.1
34	CO	% VOL	0.0
35	N_2 (BY DIFFERENCE)	% VOL	82.9
36	EXCESS AIR	%	22.6

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE	N/A	51	FLASH POINT F*	No Data
38	VOL MATTER	N/A	52	Sp. Gravity	0.9377
39	FIXED CARBON	N/A	53	VISCOSITY AT SSU* BURNER	311
40	ASH	N/A	44	TOTAL HYDROGEN % wt	11.75
	TOTAL		41	Btu per lb	18943
41	Btu per lb AS FIRED	N/A			
42	ASH SOFT TEMP.* ASTM METHOD	N/A		GAS	% VOL

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS				
			54	CO	N/A
43	CARBON	87.04	55	CH_4 METHANE	N/A
44	HYDROGEN	11.75	56	C_2H_2 ACETYLENE	N/A
45	OXYGEN	0.17	57	C_2H_4 ETHYLENE	N/A
46	NITROGEN	0.22	58	C_2H_6 ETHANE	N/A
47	SULPHUR	0.58	59	H_2S	N/A
40	ASH	0.055	60	CO_2	N/A
37	MOISTURE	0.19	61	H_2 HYDROGEN	N/A
	TOTAL			TOTAL	

	COAL PULVERIZATION				
				TOTAL HYDROGEN % wt	N/A
48	GRINDABILITY INDEX*	N/A	62	DENSITY 68 F ATM. PRESS.	N/A
49	FINENESS % THRU 50 M*	N/A	63	Btu PER CU FT	N/A
50	FINENESS % THRU 200 M*	N/A	41	Btu PER LB	N/A
64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29			78.0

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1191.6	6.3
66	HEAT LOSS DUE TO MOISTURE IN FUEL	2.2	0.01
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1250.4	6.6
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	2.4
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		18.3
72	EFFICIENCY = (100 – Item 71)		81.7

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series: Final Baseline Neat Oil	TEST NO 5	BOILER NO. 3	DATE 4/14/82
OWNER OF PLANT U.S. Coast Guard	LOCATION New London, CT		
TEST CONDUCTED BY Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 4 HR	
BOILER MAKE & TYPE Bigelow KS 20	RATED CAPACITY 28,500 lbs/hr		
STOKER TYPE & SIZE N/A			
PULVERIZER, TYPE & SIZE N/A	BURNER, SIZE(No) 116-82 (2)		
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A — SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	97.9
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	325.1
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	217.0
9	STEAM QUALITY % MOISTURE	%	0.43
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	79
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	80.7
12	TEMPERATURE OF FUEL	F	124.7
13	GAS TEMP. LEAVING (Boiler)	F	465.4
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	296.7
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1182.9
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	185.0
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	997.9
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8704
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	16.9

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	18502.4
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1265.2
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	23966.7
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	18463.8

FLUE GAS ANAL. (BOILER)(ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	13.0
33	O_2	% VOL	4.0
34	CO	% VOL	0.0
35	N_2 (BY DIFFERENCE)	% VOL	83.0
36	EXCESS AIR	%	21.9

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9377
53	VISCOSITY AT SSU* BURNER	298
44	TOTAL HYDROGEN % wt	11.75
41	Btu per lb	18943

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	87.04
44	HYDROGEN	11.75
45	OXYGEN	0.17
46	NITROGEN	0.22
47	SULPHUR	0.58
40	ASH	0.055
37	MOISTURE	0.19
	TOTAL	

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	77.0

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1561.7	8.2
66	HEAT LOSS DUE TO MOISTURE IN FUEL	2.3	0.01
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1294.1	6.8
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	1.4
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		19.5
72	EFFICIENCY = (100 – Item 71)		80.5

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series: Final Baseline Neat Oil	TEST NO 6	BOILER NO. 3	DATE 4/14/82
OWNER OF PLANT U.S. Coast Guard	LOCATION New London, CT		
TEST CONDUCTED BY Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency		DURATION 4 HR
BOILER MAKE & TYPE Bigelow KS 20		RATED CAPACITY 28,500 lbs/hr	
STOKER TYPE & SIZE N/A			
PULVERIZER, TYPE & SIZE N/A		BURNER, SIZE(No) 116-82 (2)	
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A — SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	97.9
2	STEAM PRESSURE AT S.H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R.H. INLET	psia	N/A
4	STEAM PRESSURE AT R.H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	324.9
6	STEAM TEMPERATURE AT R.H. INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	216.4
9	STEAM QUALITY % MOISTURE	%	0.46
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	79
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	79.5
12	TEMPERATURE OF FUEL	F	127.2
13	GAS TEMP. LEAVING (Boiler)	F	480.9
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	296.7
16	ENTHALPY OF (SATURATED) STM	Btu/lb	1182.7
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	184.4
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R.H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	998.3
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8704
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	16.7

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	20897.4
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1424.2
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	26978.4
30	HEAT OUTPUT IN BLOW DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	20861.4

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	13.2
33	O_2	% VOL	3.9
34	CO	% VOL	[illegible]
35	N_2 (BY DIFFERENCE)	% VOL	[illegible]
36	EXCESS AIR	%	[illegible]

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9377
53	VISCOSITY AT SSU* BURNER	283
44	TOTAL HYDROGEN % wt	11.75
41	Btu per lb	18943

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	87.04
44	HYDROGEN	11.75
45	OXYGEN	0.17
46	NITROGEN	0.22
47	SULPHUR	0.58
40	ASH	0.055
37	MOISTURE	0.19
	TOTAL	

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	77.3

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1606.3	8.5
66	HEAT LOSS DUE TO MOISTURE IN FUEL	2.3	0.01
67	HEAT LOSS DUE TO H_2O FROM COMB. OF H_2	1303.0	6.9
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	1.2
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		19.6
72	EFFICIENCY = (100 – Item 71)		80.4

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Final Baseline Neat Oil	TEST NO 7	BOILER NO 3 — DATE 4/15/82
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 4 HR
BOILER MAKE & TYPE	Bigelow KS 20	RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A		
PULVERIZER, TYPE & SIZE	N/A	BURNER, SIZE(No)	116-82 (2)
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A — SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	98.8
2	STEAM PRESSURE AT S.H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R.H. INLET	psia	N/A
4	STEAM PRESSURE AT R.H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	325.3
6	STEAM TEMPERATURE AT R.H. INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	216.1
9	STEAM QUALITY % MOISTURE	%	0.47
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	74
11	TEMP. AIR FOR COMBUSTION (This is Reference Temperature) †	F	76.0
12	TEMPERATURE OF FUEL	F	127.6
13	GAS TEMP. LEAVING (Boiler)	F	513.5
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	297.4
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1182.7
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	184.1
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R.H. OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	998.6
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8704
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	16.7

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	23540.3
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1636.6
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	31002.4
30	HEAT OUTPUT IN BLOW DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 / 1000	kB/hr	23507.9

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	13.2
33	O_2	% VOL	3.7
34	CO	% VOL	0.0
35	N_2 (BY DIFFERENCE)	% VOL	83.1
36	EXCESS AIR	%	19.9

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	87.04
44	HYDROGEN	11.75
45	OXYGEN	0.17
46	NITROGEN	0.22
47	SULPHUR	0.58
40	ASH	0.055
37	MOISTURE	0.19
	TOTAL	

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity*	0.9377
53	VISCOSITY AT SSU* BURNER	282
44	TOTAL HYDROGEN % wt	11.75
41	Btu per lb	18943

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

COAL PULVERIZATION

48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	75.8

HEAT LOSS EFFICIENCY

		Btu/lb A.F. FUEL	% of A.F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1750.3	9.2
66	HEAT LOSS DUE TO MOISTURE IN FUEL	2.4	0.01
67	HEAT LOSS DUE TO H_2O FROM COMB. OF H_2	1322.8	7.0
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	1.1
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		20.3
72	EFFICIENCY (100 – Item 71)		79.7

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1 PTC 4.1-1964

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

Test Series:	Final Baseline Neat Oil	TEST NO 8	BOILER NO. 3 DATE 4/15/82
OWNER OF PLANT	U.S. Coast Guard	LOCATION	New London, CT
TEST CONDUCTED BY	Seaworthy Engine Systems	OBJECTIVE OF TEST Measure Efficiency	DURATION 4 HR
BOILER MAKE & TYPE	Bigelow KS 20	RATED CAPACITY	28,500 lbs/hr
STOKER TYPE & SIZE	N/A		
PULVERIZER, TYPE & SIZE	N/A	BURNER, SIZE(No)	116-82 (2)
FUEL USED Oil	MINE N/A	COUNTY N/A	STATE N/A SIZE AS FIRED N/A

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	100.2
2	STEAM PRESSURE AT S. H. OUTLET	psia	N/A
3	STEAM PRESSURE AT R. H. INLET	psia	N/A
4	STEAM PRESSURE AT R. H. OUTLET	psia	N/A
5	STEAM TEMPERATURE AT OUTLET	F	326.0
6	STEAM TEMPERATURE AT R H INLET	F	N/A
7	STEAM TEMPERATURE AT R.H. OUTLET	F	N/A
8	WATER TEMP. ENTERING (BOILER)	F	217.2
9	STEAM QUALITY % MOISTURE	%	0.55
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	71
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	68.4
12	TEMPERATURE OF FUEL	F	127.6
13	GAS TEMP. LEAVING (Boiler)	F	542.2
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	N/A

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	298.5
16	ENTHALPY OF (SATURATED) STM.	Btu/lb	1182.3
17	ENTHALPY OF SAT. FEED TO (BOILER)	Btu/lb	185.2
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	N/A
19	ENTHALPY OF REHEATED STEAM R. H OUTLET	Btu/lb	N/A
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	997.1
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	N/A
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	N/A
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	N/A
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.8704
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	16.0

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	27992.8
27	REHEAT STEAM FLOW	lb/hr	N/A
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	1935.9
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	36671.1
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	N/A
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	27911.8

FLUE GAS ANAL. (BOILER)(ECON)(AIR HTR) OUTLET

32	CO_2	% VOL	13.8
33	O_2	% VOL	3.2
34	CO	% VOL	0.0
35	N_2 (BY DIFFERENCE)	% VOL	83.0
36	EXCESS AIR	%	16.8

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	N/A
38	VOL MATTER	N/A
39	FIXED CARBON	N/A
40	ASH	N/A
	TOTAL	
41	Btu per lb AS FIRED	N/A
42	ASH SOFT TEMP.* ASTM METHOD	N/A

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	87.04
44	HYDROGEN	11.75
45	OXYGEN	0.17
46	NITROGEN	0.22
47	SULPHUR	0.58
40	ASH	0.055
37	MOISTURE	0.19
	TOTAL	

	OIL	
51	FLASH POINT F*	No Data
52	Sp. Gravity	0.9377
53	VISCOSITY AT SSU BURNER	286
44	TOTAL HYDROGEN % wt	11.75
41	Btu per lb	18943

	GAS	% VOL
54	CO	N/A
55	CH_4 METHANE	N/A
56	C_2H_2 ACETYLENE	N/A
57	C_2H_4 ETHYLENE	N/A
58	C_2H_6 ETHANE	N/A
59	H_2S	N/A
60	CO_2	N/A
61	H_2 HYDROGEN	N/A
	TOTAL	
	TOTAL HYDROGEN % wt	N/A
62	DENSITY 68 F ATM. PRESS.	N/A
63	Btu PER CU FT	N/A
41	Btu PER LB	N/A

COAL PULVERIZATION

48	GRINDABILITY INDEX*	N/A
49	FINENESS % THRU 50 M*	N/A
50	FINENESS % THRU 200 M*	N/A

64	INPUT-OUTPUT EFFICIENCY OF UNIT % (ITEM 31 × 100 / ITEM 29)	76.1

HEAT LOSS EFFICIENCY

		Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1817.7	9.6
66	HEAT LOSS DUE TO MOISTURE IN FUEL	2.4	0.01
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2	1345.1	7.1
68	HEAT LOSS DUE TO COMBUST. IN REFUSE	---	---
69	HEAT LOSS DUE TO RADIATION	---	0.9
70	UNMEASURED LOSSES	---	3.0
71	TOTAL		20.6
72	EFFICIENCY = (100 – Item 71)		79.4

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

APPENDIX F

GRAPHS OF TEST EFFICIENCIES AND CURVE FITS

Figure F-1

Preliminary Neat Oil Test Efficiencies by Heat Output/Input Method

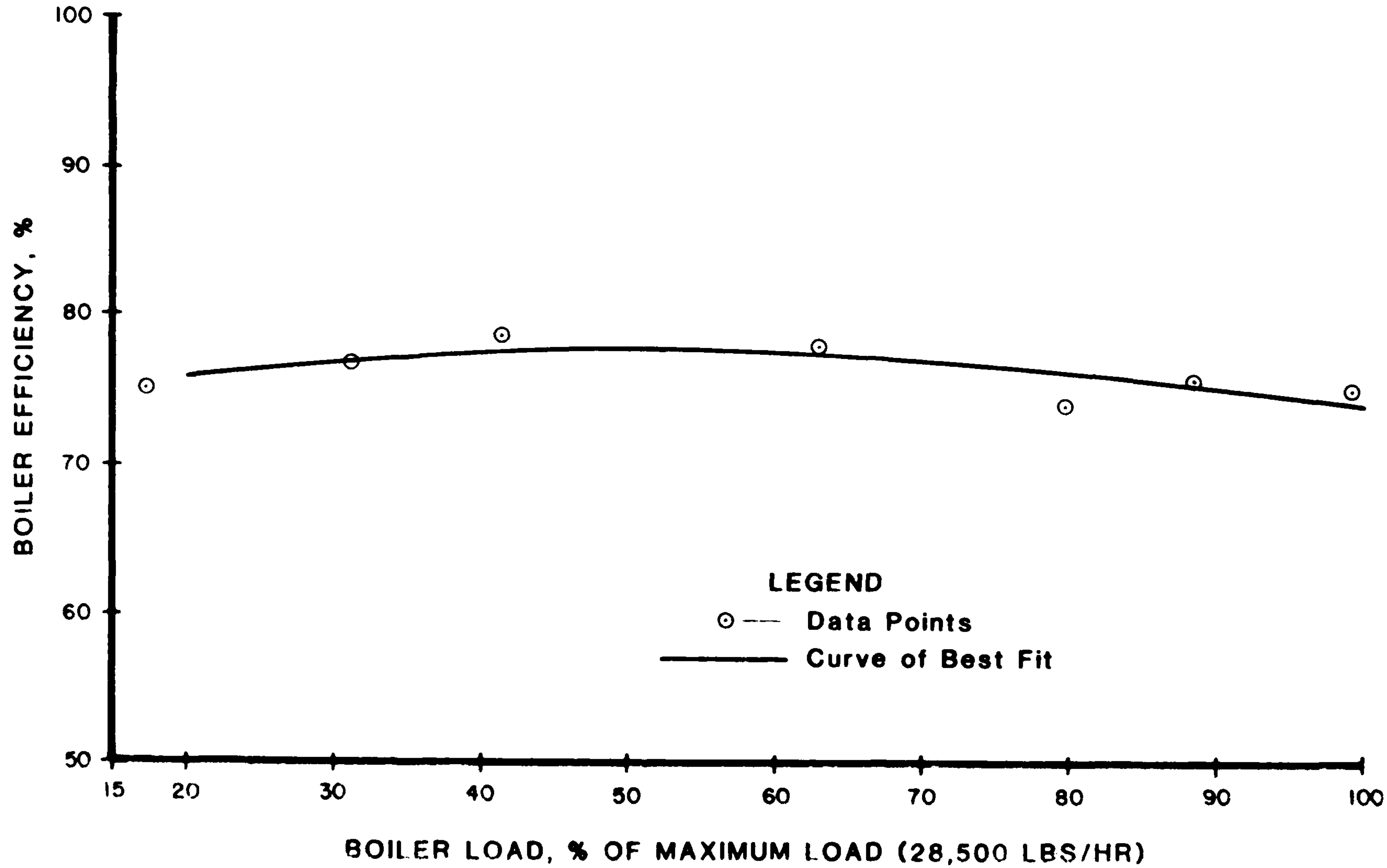


Figure F-2

Pre-Long Term Neat Oil Test Efficiencies by Heat Output/Input Method

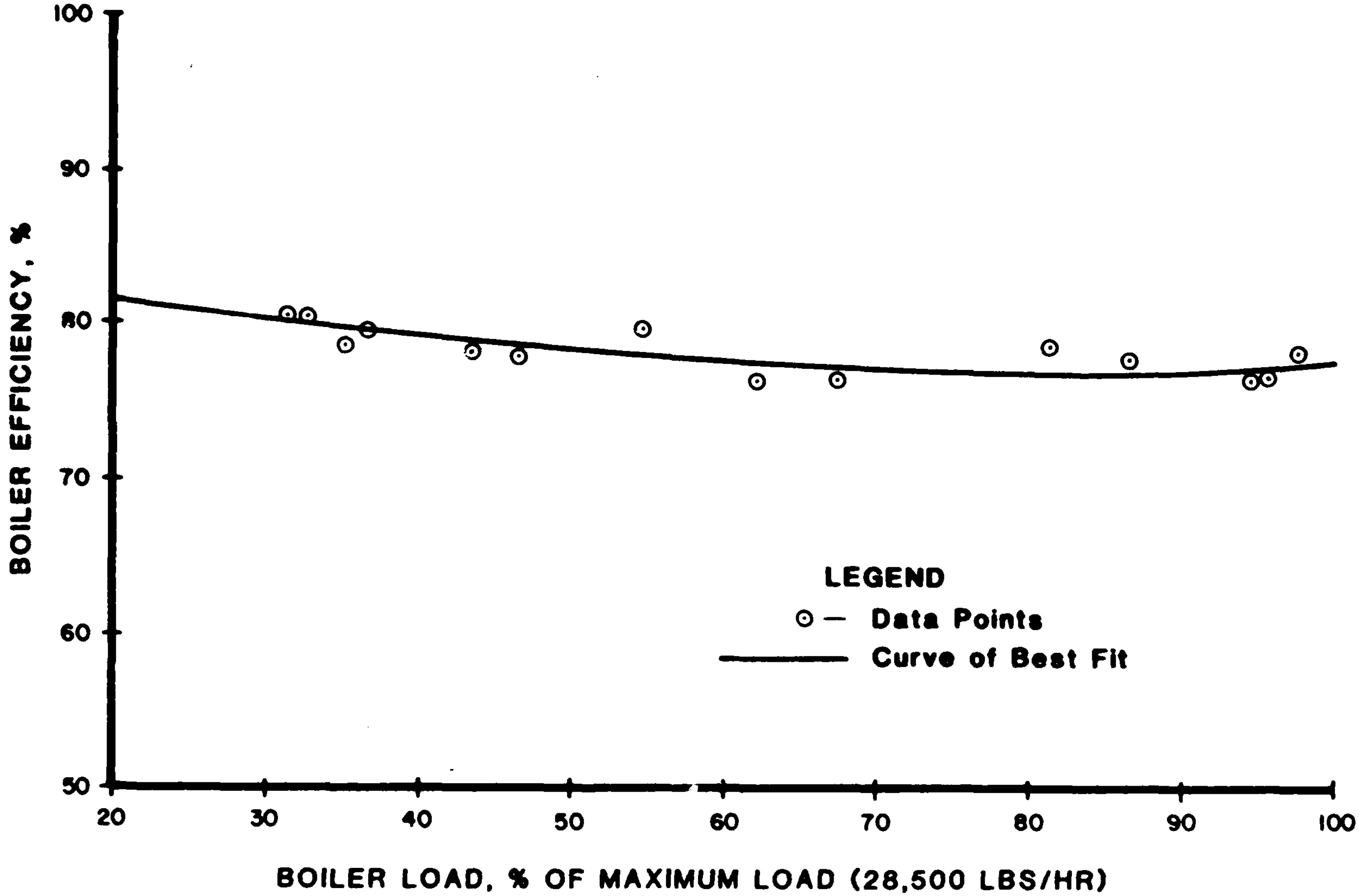


Figure F-3

Post Long Term Neat Oil Test Efficiencies by Heat Output/Input Method

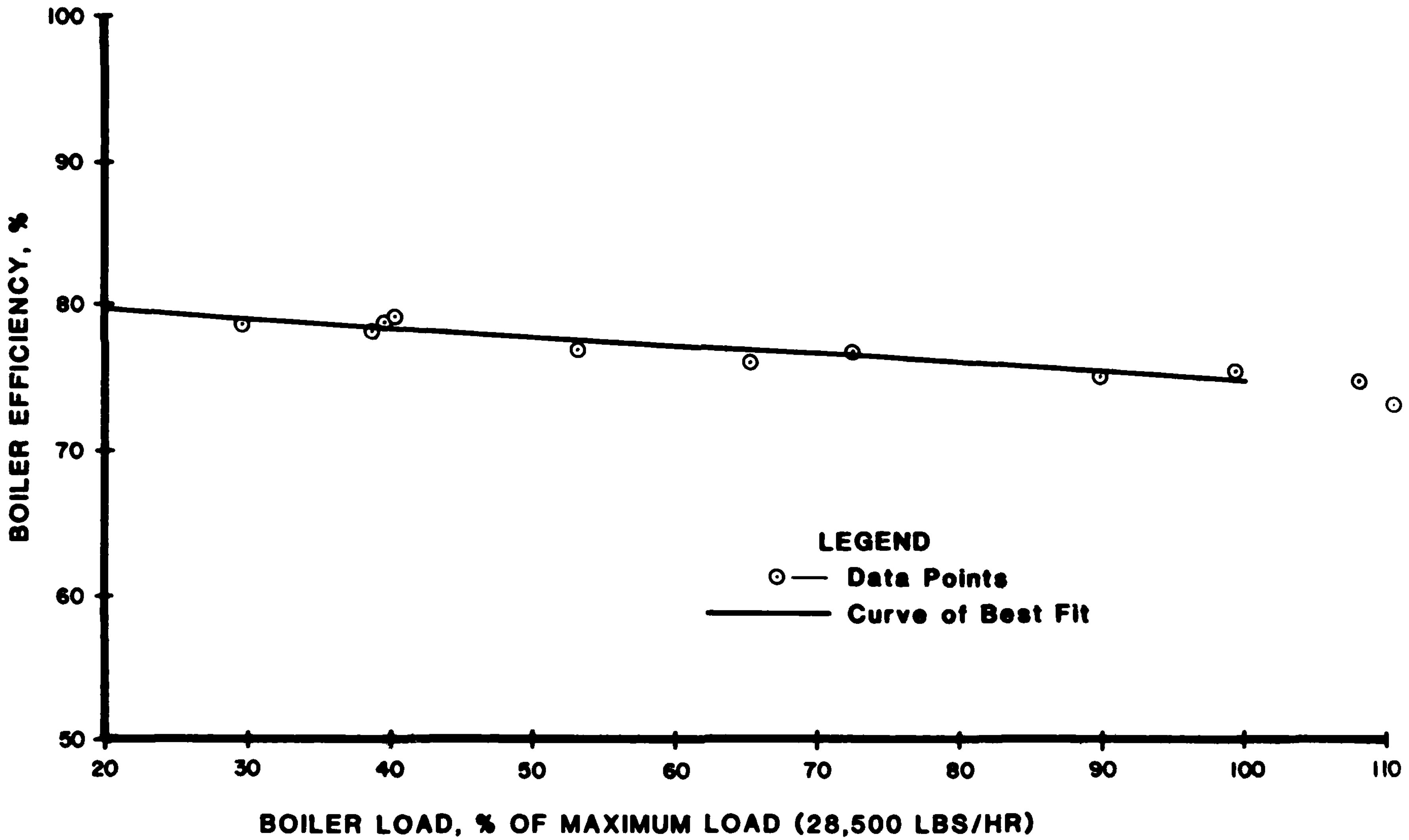


Figure F-4

Interim Base Line Neat Oil Test Efficiences by Heat Output/Input Method

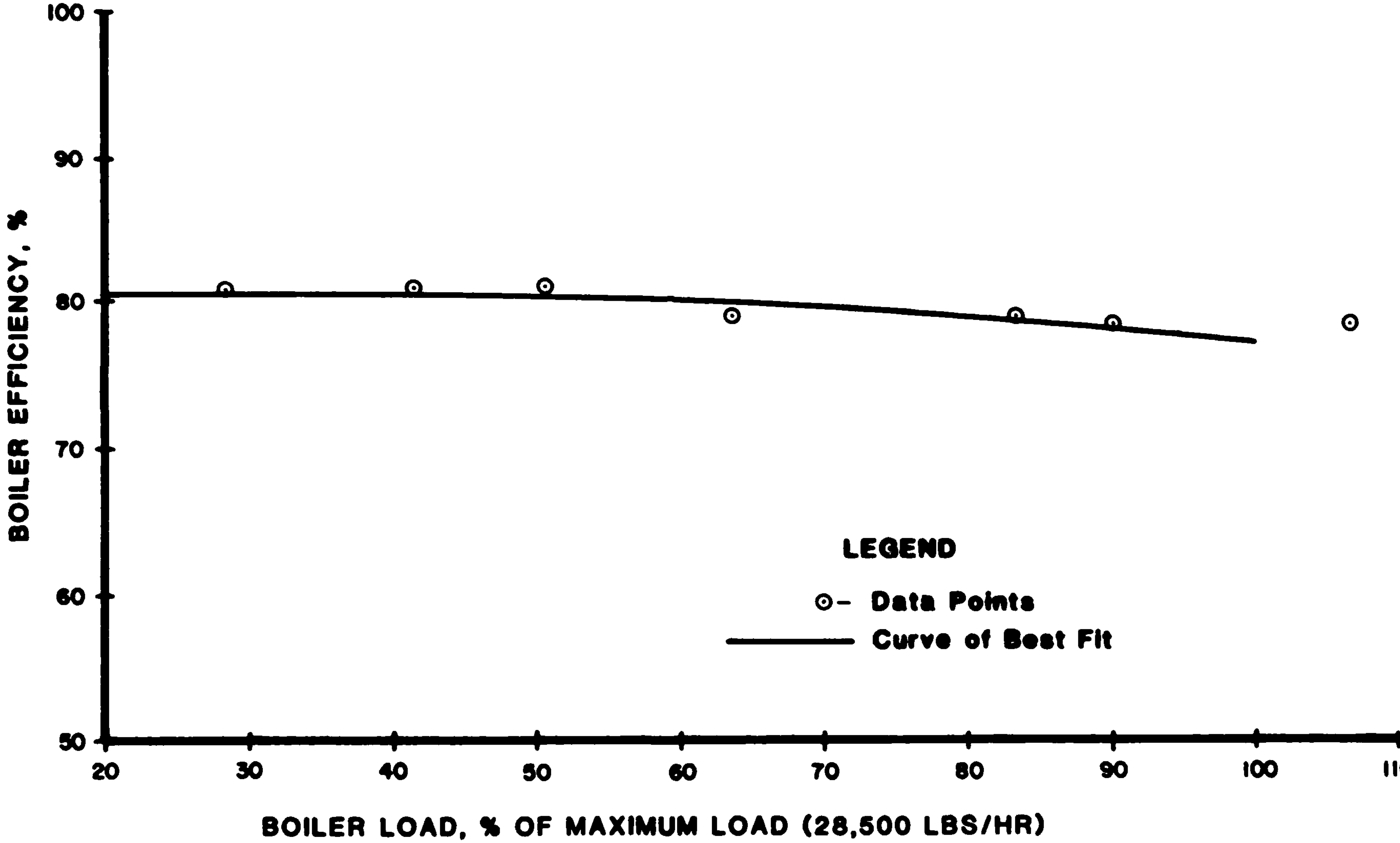


Figure F-5

Pre-Long Term Emulsified Oil Test Efficiencies by Heat Output/Input Method

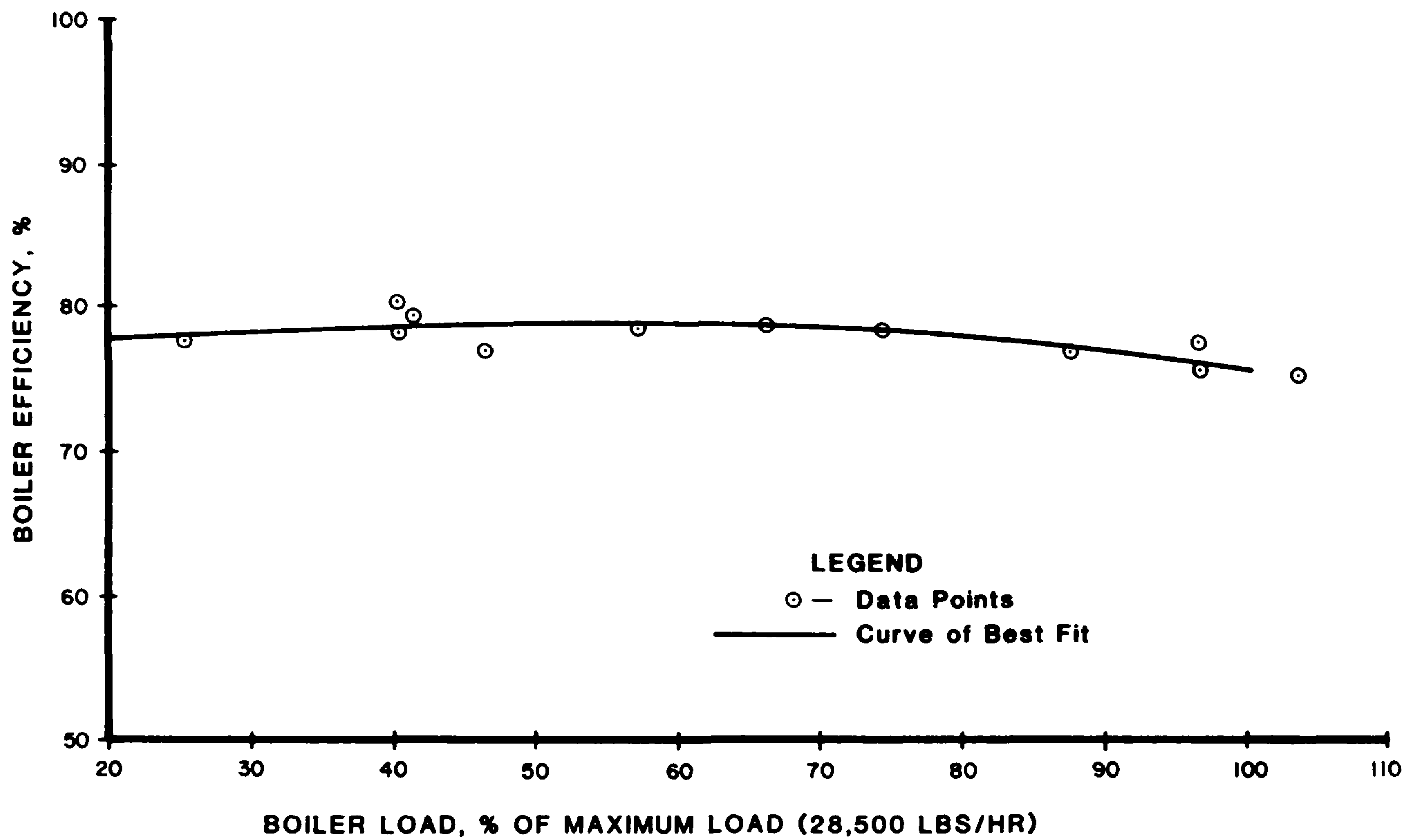


Figure F-6

Post Long Term Emulsified Oil Test Efficiencies by Heat Output/Input Method

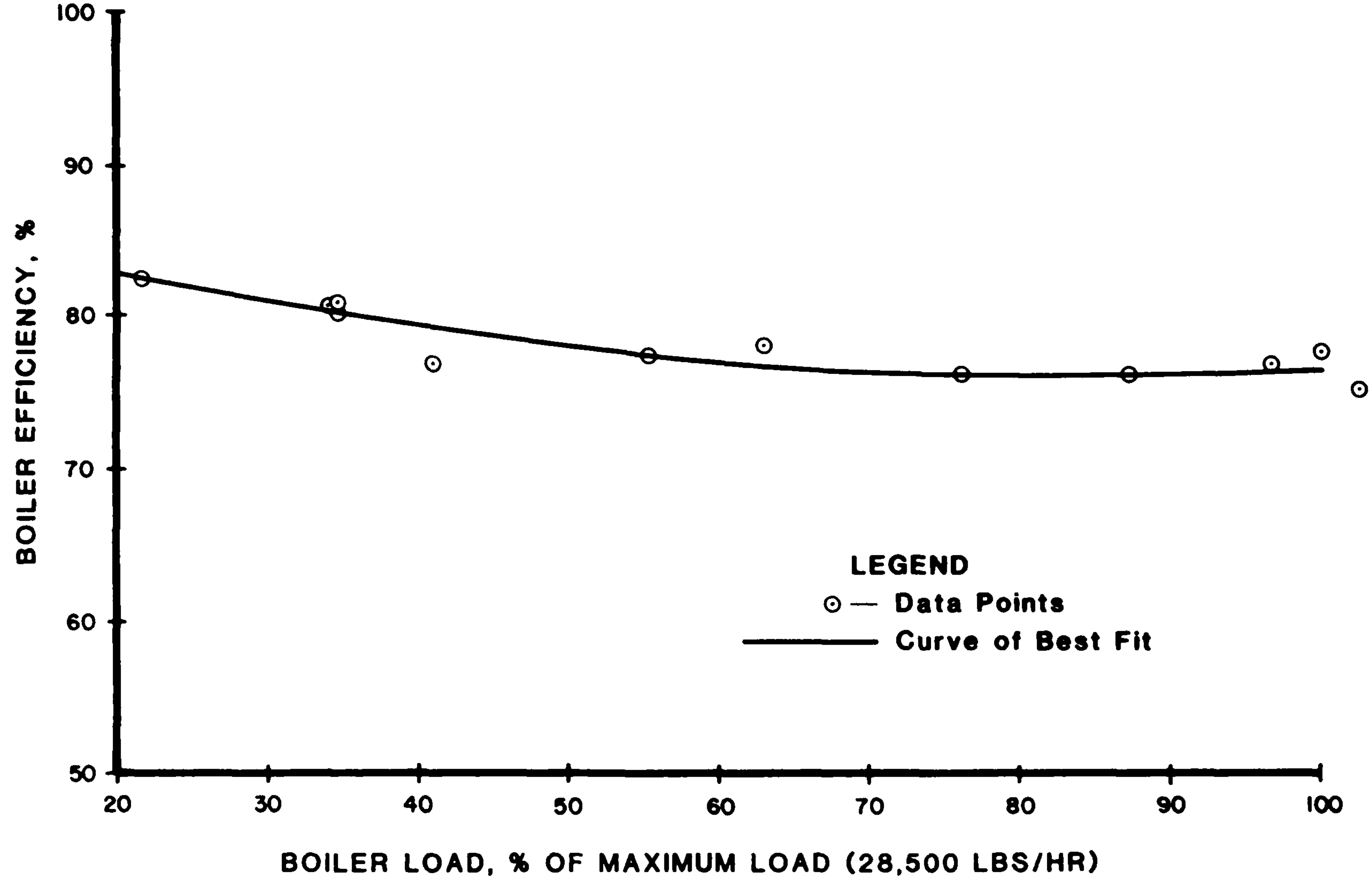
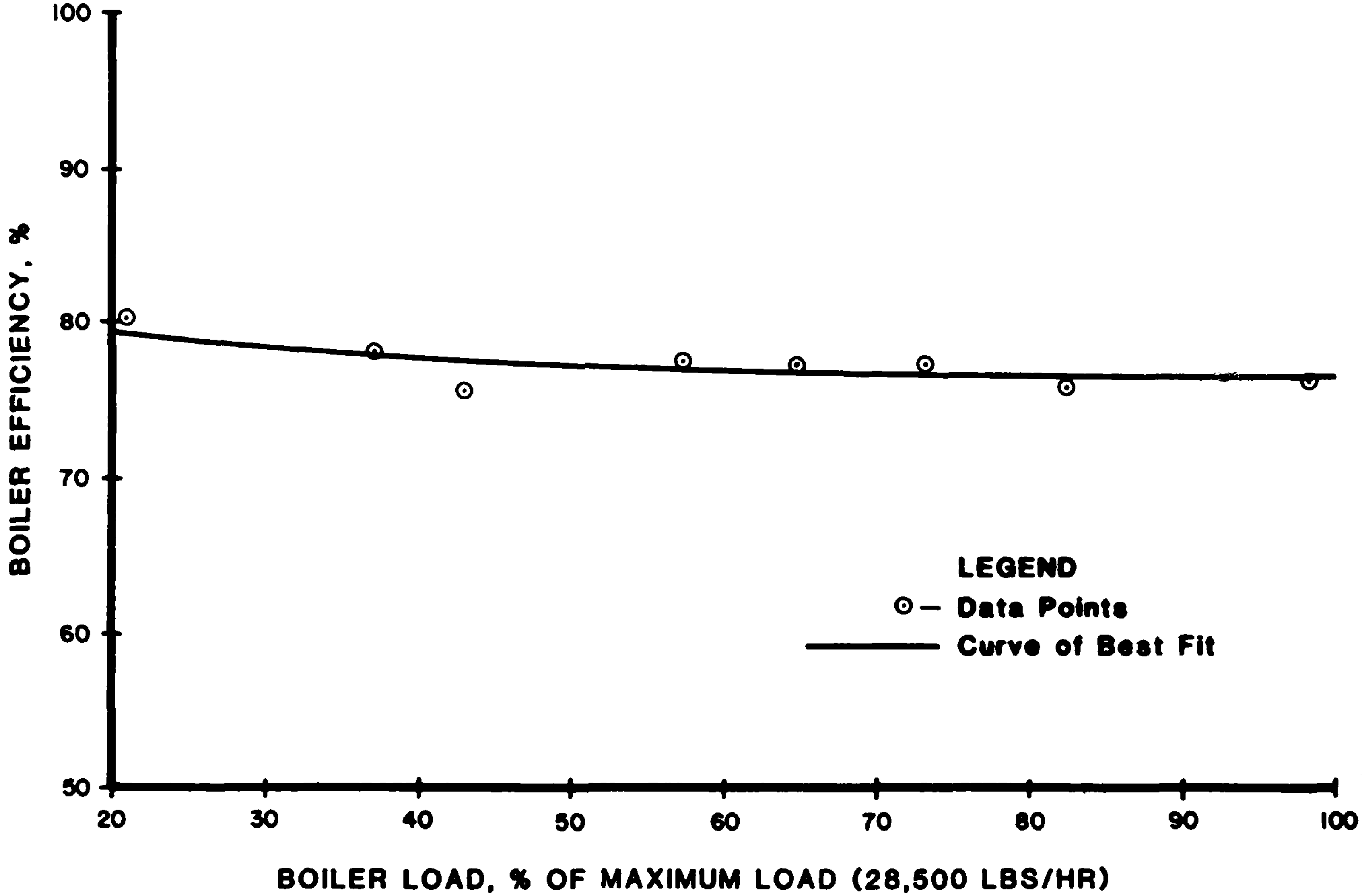


Figure F-7

Final Base Line Neat Oil Test Efficiencies by Heat Output/Input Method



APPENDIX G

SUMMARIES OF TEST BOILER COMBUSTION AND OPERATIONAL PARAMETERS DURING EFFICIENCY TESTS

TABLE G-1

SUMMARY OF PRELIMINARY NEAT OIL TESTS COMBUSTION PARAMETERS

TEST NO.	BOILER LOAD	BURNER TIP - PLUG		FUEL OIL				STEAM ATOM. PRESS.	HAGAN	COMB. AIR TEMP.	FURNACE DRAFT[A]	BOILER OUT
	% MAX. LOAD (28500 LBS/HR)	SIZE	NO. BURNERS	PRESSURE, PSIG	TEMPERATURE ^oF	VISCOSITY, SSU	CONSUMP. LBS/HR	PSIG	MASTER CONTR.	^oF	"H_2O	"H_2O
1	17.4	86-60	1	43.4	185.3	160[B]	353.4	64	34	84.4	0.23	-0.66
2	31.3	86-60	2	39.8	185.4	160[B]	623.2	61	44	91.6	0.06	-0.67
3	41.5	102-73	2	33.9	184.1	162[B]	798.3	55	21	84.6	0.17	-0.69
5	63.0	109-78	2	52.4	177.2	167[C]	1221.2	72	43	83.0	0.89	-0.74
6	79.9	109-78	2	66.4	185.8	158[C]	1638.1	81	58	83.5	1.53	-0.91
7	88.4	125-89	2	52.9	157.5	294[C]	1767.9	72	49	82.6	1.11	-0.90
8	99.1	125-89	2	62.2	162.2	267[C]	2060.8	79	59	86.1	1.74	-0.90

(A) Furnace Draft - Furnace Pressure - Windbox Pressure

(B) Calculated from Temperature and Fuel Analysis

(C) Viscosity from Norcrosse Viscosity Meter

TABLE G-2

SUMMARY OF PRELIMINARY NEAT OIL TESTS OPERATING PARAMETERS

TEST NO.	BOILER LOAD	STEAM			FEED WATER			FLUE GAS						FORCED DRAFT FAN	
	% MAX. LOAD (28500 LBS/HR)	PRESS. PSIA	TEMP. ^oF	QUALITY % H_2O	PRESS. PSIG	TEMP. ^oF	FLOW RATE LBS/HR	TEMP. ^oF	CO_2, % BY VOL.	O_2%, BY VOL.	CO ppm[A]	EXCESS AIR, %	OPACITY, %	AMPS	VOLTS
1	17.4	100.7	325.7	1.46	84.6[C]	213.8	4,970	348.3	6.5	12.6	106	138	13.6	ND[B]	ND
2	31.3	100.1	325.2	1.50	84.5	209.4	8,933	390.1	9.1	9.3	12	74	13.9	ND	ND
3	41.5	102.6	326.8	1.50	87.1	218.5	11,830	413.0	10.4	7.6	13	53	16.4	12	205
5	63.0	101.8	325.7	2.39	86.2	214.8	17,959	486.7	10.4	7.6	6	53	15.3	15	204
6	79.9	101.7	325.0	1.48	86.0	216.8	22,778	547.3	10.4	7.7	8	54	20.9	17	205
7	88.4	102.1	324.8	1.59	86.6	218.6	25,190	534.4	13.1	4.4	49	25	25.3	14	204
9	99.1	101.7	324.2	1.88	86.1	183.5	28,254	571.2	12.9	4.2	90	23	24.3	17	204

(A) ppm = Parts per Million by volume

(B) ND - No Data

(C) Feedwater pressure should be higher than steam pressure. Suspect feed water gage because steam gage was calibrated prior to test.

TABLE G-3

SUMMARY OF PRE LONG TERM NEAT OIL EFFICIENCY TESTS COMBUSTION PARAMETERS

TEST NO.	BOILER LOAD	BURNER TIP - PLUG		FUEL OIL				STEAM ATOM. PRESS.	HAGAN	COMB. AIR TEMP.	FURNACE DRAFT[A]	BOILER OUT
	% MAX. LOAD (28500 LBS/HR)	SIZE	NO. BURNERS	PRESSURE, PSIG	TEMPERATURE ^oF	VISCOSITY, SSU	CONSUMP. LBS/HR	PSIG	MASTER CONTR.	^oF	"H_2O	"H_2O
1	36.8	116-82	2	21.6	168.8	208	711.4	43	14	71.9	ND	-0.72
2	35.4	116-82	2	20.3	168.2	210	692.8	42	13	80.7	ND	-0.72
3	31.4	116-82	2	19.7	165.9	217	599.8	41	13	81.3	ND	-0.71
4	32.8	116-82	2	19.6	164.2	244	628.1	41	12	81.5	ND	-0.70
5	95.6	116-82	2	64.4	162.9	251	1915.6	82	52	82.0	1.01	-0.92
6	97.8	116-82	2	66.3	163.7	256	1922.4	83	46	78.9	1.05	-0.94
7	94.8	116-82	2	64.7	160.3	277	1901.4	82	48	79.0	1.10	-0.94
8	81.4	116-82	2	56.5	167.1	238	1589.2	73	40	76.6	0.72	-0.86
9	54.9	116-82	2	34.4	166.4	250	1055.8	55	29	74.3	0.17	-0.76
10	46.8	116-82	2	28.4	158.7	291	921.1	50	16	73.0	0.06	-0.73
11	62.2	116-82	2	42.2	158.3	307	1253.8	62	24	72.5	0.37	-0.79
10R	43.7	116-82	2	26.3	151.4	256	862.4	47	58	65.1	0.07	-0.72
11R	67.5	116-82	2	42.0	149.5	262	1353.6	62	66	71.0	0.53	-0.80
12R	86.6	116-82	2	54.3	147.2	276	1711.0	73	72	74.8	0.90	-0.88

A - Furnace Draft = Furnace Pressure - Windbox Pressure
ND - No Data

TABLE G-4

SUMMARY OF PRE LONG TERM NEAT OIL EFFICIENCY TESTS OPERATION PARAMETERS

TEST NO.	BOILER LOAD	STEAM			FEED WATER			FLUE GAS						FORCED DRAFT FAN	
	% MAX. LOAD (28500 LBS/HR)	PRESS. PSIA	TEMP. °F	QUALITY % H_2O	PRESS. PSIG	TEMP. °F	FLOW RATE LBS/HR	TEMP. °F	CO_2, % BY VOL.	O_2%, BY VOL.	CO ppm[A]	EXCESS AIR, %	OPACITY, %	AMPS	VOLTS
1	36.8	102.8	328.7	0.63	89.5	217.1	10493.7	380.8	11.8	5.5	61.5	32.5	11.9	11	206
2	35.4	101.4	328.0	0.45	88.4	218.4	10088.9	383.9	12.5	4.5	13.6	25.3	19.1	11	206
3	31.4	101.2	327.8	0.39	88.0	218.7	8940.0	353.5	11.5	5.3	10.3	31.2	10.9	11	208
4	32.8	100.5	327.2	0.35	87.3	218.3	9350.2	352.9	11.6	5.1	74	29.5	17.2	11	206
5	95.6	102.9	327.3	0.38	90.2	218.8	27249.6	549.5	12.9	4.3	64	24.0	23	15.2	207
6	97.8	103.3	327.4	0.35	90.5	219.3	27860.3	550.5	13.6	3.6	36.8	19.3	20.2	15.0	207
7	94.8	101.1	326.3	0.35	88.7	219.2	27004.2	552.3	13.5	3.4	36.2	18.0	14.7	14.8	209
8	81.4	101.1	326.8	0.35	88.5	219.6	23213.2	505.3	13.3	4.2	22.6	23.4	13.8	13.5	209
9	54.9	100.0	326.6	0.49	87.0	220.4	15638.7	437.1	12.7	4.5	95.4	25.4	19.4	12.1	209
10	46.8	101.1	327.8	0.57	88.0	220.6	13328.5	417.3	13.0	4.1	124	22.6	17.7	11.9	209
11	62.2	99.1	325.5	0.36	85.9	218.4	17722.6	471.0	13.2	3.8	54.4	20.6	14.6	11.8	209
10R	43.7	99.6	325.5	0.73	86.1	210.6	12467.0	415.2	12.5	4.3	ND	23.9	17.7	11.8	209
11R	67.5	99.3	325.5	0.54	86.2	215.8	19227.6	505.7	12.7	4.0	ND	21.8	18.4	13.0	209
12R	86.6	99.9	324.9	0.60	87.1	215.1	24693.6	534.0	13.5	2.9	ND	14.9	20.5	14.3	210

A - ppm = Parts per Million by volume
ND - No Data

TABLE G-5

SUMMARY OF POST LONG TERM NEAT OIL EFFICIENCY TESTS COMBUSTION PARAMETERS

TEST NO.	BOILER LOAD	BURNER TIP - PLUG		FUEL OIL				STEAM ATOM. PRESS.	HAGAN	COMB. AIR TEMP.	FURNACE DRAFT[A]	BOILER OUT
	% MAX. LOAD (28500 LBS/HR)	SIZE	NO. BURNERS	PRESSURE, PSIG	TEMPERATURE °F	VISCOSITY, SSU	CONSUMP. LBS/HR	PSIG	MASTER CONTR.	°F	"H_2O	"H_2O
1	39.1	116-82	2	19.6	119.1	89	733.0	39	26	76.0	0.03	-0.78
2	39.8	116-82	2	20.1	120.6	124	744.8	40	24	77.3	0.03	-0.78
3	40.4	116-82	2	20.4	120.2	145	752.7	40	22	81.9	0.03	-0.79
4	110.9	116-82	2	58.0	121.6	136	2235.1	75	60	77.5	2.07	-1.08
5	99.4	116-82	2	53.4	121.1	140	1949.0	71	47	75.9	1.27	-1.0
6	108.1	116-82	2	53.2	123.1	132	2149.3	71	54	72.4	1.66	-1.1
7	90.0	116-82	2	45.3	123.7	133	1785.3	63	49	78.9	1.28	-1.0
9	53.4	116-82	2	27.0	120.7	147	1061.4	46	32	67.3	0.28	-0.81
10R	65.6	116-82	2	32.1	122.8	135	1280.6	51	36	77.4	0.49	-0.87
11	72.8	116-82	2	37.0	120.8	148	1398.7	56	39	72.6	0.62	-0.89
12	30.0	116-82	1	28.0	117.4	161	570.6	48	30	72.0	0.17	-0.77

A - Furnace Draft = Windbox Pressure - Furnace Pressure

TABLE G-6

SUMMARY OF POST LONG TERM NEAT OIL EFFICIENCY TESTS OPERATIONAL PARAMETERS

TEST NO.	BOILER LOAD	STEAM			FEED WATER			FLUE GAS						FORCED DRAFT FAN	
	% MAX. LOAD (28500 LBS/HR)	PRESS. PSIA	TEMP. °F	QUALITY % H_2O	PRESS. PSIA	TEMP. °F	FLOW RATE LBS/HR	TEMP. °F	CO_2, % BY VOL.	O_2%, BY VOL.	CO ppm[A]	EXCESS AIR, %	OPACITY, %	AMPS	VOLTS
1	39.1	99	328.0	0.64	101.1	221.5	11143	411.5	11.8	5.2	ND	30.5	9.1	11.0	207
2	39.8	100	327.9	0.55	100.6	220.2	11350	414.4	12.0	5.0	284	28.9	9.2	11.0	207
3	40.4	101	328.3	0.54	100.7	219.7	11515	415.9	11.4	5.9	59	36.2	10.1	11.0	208
4	110.9	105	329.6	1.34	106.0	212.0	31619	689.9	12.7	3.9	78	21.1	9.0	17.0	207
5	99.4	105	329.7	1.13	105.8	212.1	28337	611.4	13.6	3.3	114	17.4	10.2	13.8	208
6	108.1	105	329.7	0.50	106.5	210.6	30812	653.0	13.1	4.1	83	22.6	8.6	15.3	208
7	90.1	103	329.1	0.31	104.1	209.8	25664	588.8	12.1	5.2	142	30.6	8.6	13.9	209
9	53.4	101	328.5	0.48	102.2	181.8	15212	461.1	12.0	5.1	158	29.7	10.2	11.0	210
10R	65.6	102	328.4	0.47	101.9	214.4	18693	496.1	12.4	4.4	186	24.5	11.2	11.4	212
11	72.8	102	328.4	0.45	102.6	219.6	20758	519.0	12.7	4.1	190	22.4	9.3	11.8	210
12	30.0	102	328.9	0.32	101.3	206.7	8546	356.2	11.2	6.2	122	38.8	9.2	3.8	211

A - ppm - Parts per Million by volume
ND - No data

TABLE G-7

SUMMARY OF INTERIM BASELINE NEAT OIL EFFICIENCY TESTS COMBUSTION PARAMETERS

TEST NO.	BOILER LOAD	BURNER TIP - PLUG		FUEL OIL				STEAM ATOM. PRESS.	HAGAN	COMB. AIR TEMP.	FURNACE DRAFT[A]	BOILER OUT
	% MAX. LOAD (28500 LBS/HR)	SIZE	NO. BURNERS	PRESSURE, PSIG	TEMPERATURE ^{o}F	VISCOSITY, SSU	CONSUMP. LBS/HR	PSIG	MASTER CONTR.	^{o}F	"H_2O	"H_2O
1	28.6	116-82	1	25.7	121.2	216	561.2	44	32	75.9	0.18	-0.89
2R	41.6	116-82	2	17.4	125.9	192	796.2	35	26	77.9	0.13	-0.91
3	50.8	116-82	2	21.4	119.3	232	937.4	39	28	82.8	0.26	-0.92
4	63.6	116-82	2	28.8	120.4	210	1237.5	46	34	77.1	0.55	-0.95
6	83.4	116-82	2	35.5	119.0	232	1618.2	52	40	75.1	1.18	-1.0
7	90.1	116-82	2	43.2	121.3	196	1759.2	59	65	83.5	1.24	-0.98
8	106.7	116-82	2	49.7	120.3	239	2091.0	65	70	81.5	1.91	-1.0

A Furnace Draft = Furnace Pressure - Windbox Pressure

TABLE G-8

SUMMARY OF INTERIM BASELINE NEAT OIL EFFICIENCY TESTS OPERATION PARAMETERS

TEST NO.	BOILER LOAD	STEAM			FEED WATER			FLUE GAS						FORCED DRAFT FAN	
	% MAX. LOAD (28500 LBS/HR)	PRESS. PSIA	TEMP. °F	QUALITY % H_2O	PRESS. PSIA	TEMP. °F	FLOW RATE LBS/HR	TEMP. °F	CO_2, % BY VOL.	O_2%, BY VOL.	CO ppm[A]	EXCESS AIR, %	OPACITY, %	AMPS	VOLTS
1	28.6	100.2	326.5	0.31	99.0	157.9	8150.4	349.0	10.5	6.9	120	45.2	15	4	208
2R	41.6	98.3	325.4	0.47	97.2	183.2	11869.8	398.2	11.2	6.2	130	38.8	13	10	210
3	50.8	97.4	324.9	0.48	96.6	216.2	14492.8	423.5	11.8	5.5	96	32.9	13	10	210
4	63.6	99.0	325.2	0.54	98.2	185.4	18118.0	468.0	12.0	5.2	101	30.5	13	10	205
6	83.4	100.0	325.4	0.43	99.1	190.9	23770.6	523.6	12.4	4.8	77	27.5	13	16	209
7	90.1	98.3	324.2	0.58	97.7	193.2	25690.8	531.8	12.0	4.2	162	23.0	12	17	208
8	106.7	98.8	323.5	0.67	97.7	214.5	30415.0	568.3	13.1	3.7	73	19.8	13	19	208

A - ppm = parts per million by volume

TABLE G-9

SUMMARY OF PRE LONG TERM EMULSIFIED OIL EFFICIENCY AND EMISSION TESTS COMBUSTION PARAMETERS

TEST NO.	BOILER LOAD	BURNER TIP - PLUG		FUEL OIL				STEAM ATOM. PRESS.	HAGAN	COMB. AIR TEMP.	FURNACE DRAFT[A]	BOILER OUT
	% MAX. LOAD (28500 LBS/HR)	SIZE	NO. BURNERS	PRESSURE, PSIG	TEMPERATURE ^oF	VISCOSITY, SSU	CONSUMP. LBS/HR	PSIG	MASTER CONTR.	^oF	"H_2O	"H_2O
1	25.4	116-82	1	21.0	121.2	113	512.7	42	30	80.0	0.06	-0.66
2	41.4	116-82	2	17.0	120.7	114	812.8	37	26	84.0	0.06	-0.70
3	40.5	116-82	2	17.2	121.0	115	810.0	37	26	84.3	0.09	-0.70
4	40.3	116-82	2	16.7	120.7	117	782.9	37	25	85.7	0.06	-0.70
5	103.8	116-82	2	52.4	120.1	122	2158.1	68	55	82.9	2.1	-1.0
6	96.6	116-82	2	46.8	120.5	120	1943.1	64	46	81.7	1.4	-1.0
7	96.8	116-82	2	47.1	119.9	130	2005.1	64	48	79.4	1.5	-1.0
8	86.7	116-82	2	42.8	120.4	122	1763.9	60	44	79.2	1.2	-1.0
9	46.4	116-82	2	19.2	120.8	125	944.0	39	26	76.9	0.14	-0.91
10	57.3	116-82	2	24.4	121.0	131	1133.4	43	31	85.3	0.33	-0.95
11	66.2	116-82	2	27.5	120.3	131	1312.1	46	36	85.4	0.58	-0.98
12	74.4	116-82	2	32.3	119.9	137	1478.8	50	38	78.3	0.71	-1.0

A - Furnace Draft = Furnace Pressure - Windbox Pressure

TABLE G-10

SUMMARY OF PRE LONG TERM EMULSIFIED OIL EFFICIENCY AND EMISSION TESTS OPERATIONAL PARAMETERS

TEST NO.	BOILER LOAD	STEAM			FEED WATER			FLUE GAS						FORCED DRAFT FAN	
	% MAX. LOAD (28500 LBS/HR)	PRESS. PSIA	TEMP. °F	QUALITY % H_2O	PRESS. PSIA	TEMP. °F	FLOW RATE LBS/HR	TEMP. °F	CO_2, % BY VOL.	O_2%, BY VOL.	CO ppm[A]	EXCESS AIR, %	OPACITY, %	AMPS	VOLTS
1	25.4	97.4	324.2	0.32	95.7	219.3	7249.6	332.5	12.1	5.1	60	29.8	17	4.5	207
2	41.4	97.7	324.2	0.47	95.2	221.1	11800.1	388.1	12.8	4.4	94	24.7	17	12	207
3	40.5	98.0	324.4	0.51	96.0	219.2	11553.6	391.2	12.0	5.2	60	30.5	16	13	207
4	40.3	98.1	324.3	0.50	95.8	220.1	11481.8	385.4	12.3	5.0	70	29.1	16	12	207
5	103.8	98.5	323.8	0.49	98.5	214.8	29574.7	584.3	12.7	4.6	110	26.1	17	21	207
6	96.6	97.9	323.4	0.48	97.3	218.3	27542.1	548.9	13.0	4.0	105	21.9	15	18	207
7	96.8	98.0	323.5	0.40	97.6	214.9	27576.8	558.4	13.0	4.1	120	22.6	16	18	207
8	86.7	98.8	324.2	0.44	97.9	217.5	24706.2	536.2	12.7	4.6	87	26.1	14	17	207
9	46.4	97.3	324.1	0.44	96.2	216.7	13215.0	413.0	11.7	5.4	62	32.0	16	13	207
10	57.3	97.9	324.1	0.42	96.3	221.7	16324.0	443.6	12.0	5.2	144	30.5	16	14	207
11	66.2	99.3	324.7	0.44	97.2	221.4	18871.2	480.5	11.9	5.4	118	32.1	15	14	207
12	74.4	100.0	325.1	0.41	98.3	220.7	21201.2	504.6	12.4	4.8	135	27.5	14	16	207

A - ppm = parts per million by volume

TABLE G-11

SUMMARY OF POST LONG TERM EMULSIFIED OIL EFFICIENCY AND EMISSION TESTS COMBUSTION PARAMETERS

TEST NO.	BOILER LOAD	BURNER TIP - PLUG		FUEL OIL				STEAM ATOM. PRESS.	HAGAN	COMB. AIR TEMP.	FURNACE DRAFT[A]	BOILER OUT
	% MAX. LOAD (28500 LBS/HR)	SIZE	NO. BURNERS	PRESSURE, PSIG	TEMPERATURE °F	VISCOSITY, SSU	CONSUMP. LBS/HR	PSIG	MASTER CONTR.	°F	"H_2O	"H_2O
1	102.4	116-82	2	52.0	118.8	300	2166.0	69	50	73.3	1.83	-0.95
2	99.9	116-82	2	51.2	120.6	282	2110.6	68	52	77.7	1.64	-0.95
3	96.7	116-82	2	50.6	120.6	282	1991.5	68	45	80.5	1.30	-0.90
4	34.7	116-82	2	15.8	121.0	273	681.4	35	30	74.0	0.03	-0.67
5	34.1	116-82	2	15.6	118.5	293	671.7	35	31	74.9	0.03	-0.65
6	34.6	116-82	2	15.7	124.3	260	684.5	35	30	73.9	0.03	-0.68
7R	21.8	116-82	1	20.3	118.5	295	420.0	40	22	76.3	0.03	-0.65
8	41.0	116-82	2	18.7	118.2	298	840.8	38	38	75.5	0.12	-0.69
9	55.2	116-82	2	25.1	119.4	288	1136.0	44	48	77.6	0.33	-0.73
10	63.0	116-82	2	30.2	119.4	290	1282.6	48	54	80.7	0.49	-0.75
11	76.1	116-82	2	35.4	119.3	290	1590.5	53	40	76.9	0.82	-0.80
12	87.1	116-82	2	41.5	119.9	285	1825.6	59	44	82.0	1.15	-0.85

A - Furnace Draft = Furnace Pressure - Windbox Pressure

TABLE G-12

SUMMARY OF POST LONG TERM EMULSIFIED OIL EFFICIENCY AND EMISSION TESTS OPERATIONAL PARAMETERS

TEST NO.	BOILER LOAD	STEAM			FEED WATER			FLUE GAS						FORCED DRAFT FAN	
	% MAX. LOAD (28500 LBS/HR)	PRESS. PSIA	TEMP. °F	QUALITY % H_2O	PRESS. PSIA	TEMP. °F	FLOW RATE LBS/HR	TEMP. °F	CO_2, % BY VOL.	O_2%, BY VOL.	CO ppm[A]	EXCESS AIR, %	OPACITY, %	AMPS	VOLTS
1	102.4	99.1	325.3	0.69	101.4	215.9	29188.6	599.8	13.1	3.9	20	21.2	20	18	205
2	99.9	99.3	325.2	0.80	100.9	220.3	28467.2	594.2	13.0	4.2	18	23.3	20	19	205
3	96.7	98.5	324.8	0.69	99.9	221.3	27548.1	562.2	14.2	2.8	48	14.4	20	17	205
4	34.7	95.5	324.2	0.39	96.6	217.9	9880.2	349.8	12.8	4.4	35	24.7	20	6	206
5	34.1	96.2	324.6	0.40	97.0	218.4	9724.7	349.6	12.8	4.5	70	25.4	20	6	206
6	34.6	95.6	324.3	0.34	96.9	218.7	987[illegible].1	352.1	12.9	4.3	82	24.0	21	6	207
7R	21.8	95.8	324.3	0.27	96.2	218.8	6214.3	323.6	11.8	5.5	22	33.0	19	6	206
8	41.0	97.0	325.0	0.42	97.7	217.1	11694.7	394.5	12.6	4.4	32	24.6	20	6	205
9	55.2	98.2	325.7	0.26	99.0	218.9	15733.5	443.9	12.7	4.2	40	23.2	21	6	205
10	63.0	98.2	325.6	0.28	99.1	217.8	17944.1	462.4	13.0	3.8	45	20.5	20	6	205
11	76.1	98.9	326.0	0.39	100.7	216.8	21696.2	512.1	13.2	3.8	46	20.6	21	16	208
12	87.1	99.6	326.1	0.36	100.9	214.8	24822.3	547.5	13.1	3.7	36	19.9	22	17	204

A - ppm = parts per million by volume

TABLE G-13

SUMMARY OF FINAL BASELINE NEAT OIL EFFICIENCY TESTS COMBUSTION PARAMETERS

TEST NO.	BOILER LOAD	BURNER TIP - PLUG		FUEL OIL				STEAM ATOM. PRESS.	HAGAN	COMB. AIR TEMP.	FURNACE DRAFT[A]	BOILER OUT
	% MAX. LOAD (28500 LBS/HR)	SIZE	NO. BURNERS	PRESSURE, PSIG	TEMPERATURE ^oF	VISCOSITY, SSU	CONSUMP. LBS/HR	PSIG	MASTER CONTR.	^oF	"H_2O	"H_2O
1	43.2	116-82	2	22.0	124.6	221	851.0	39	36	78.9	0.13	-0.70
2	57.6	116-82	2	27.6	125.3	215	1105.3	45	48	85.3	0.40	-0.73
3	21.2	116-82	1	21.0	119.1	333	396.7	39	24	80.2	0.03	-0.67
4	37.3	116-82	2	19.0	122.6	311	716.7	37	35	78.4	0.03	-0.68
5	64.9	116-82	2	32.9	124.7	298	1265.2	50	58	80.7	0.55	-0.76
6	73.3	116-82	2	37.3	127.2	283	1424.2	53	39	79.5	0.75	-0.80
7	82.6	116-82	2	45.0	127.6	282	1636.6	61	42	76.0	1.03	-0.89
8	98.2	116-82	2	51.2	127.6	286	1935.9	66	46	68.4	1.38	-0.89

A - Furnace Draft = Furnace Pressure - Windbox Pressure

TABLE G-14

SUMMARY OF FINAL BASELINE NEAT OIL EFFICIENCY TESTS OPERATIONAL PARAMETERS

TEST NO.	BOILER LOAD	STEAM			FEED WATER			FLUE GAS						FORCED DRAFT FAN	
	% MAX. LOAD (28500 LBS/HR)	PRESS. PSIA	TEMP. ^oF	QUALITY % H_2O	PRESS. PSIA	TEMP. ^oF	FLOW RATE LBS/HR	TEMP. ^oF	CO_2, % BY VOL.	O_2%, BY VOL.	CO ppm[A]	EXCESS AIR, %	OPACITY, %	AMPS	VOLTS
1	43.2	96.7	324.7	0.39	97.0	215.2	12302.4	408.2	12.8	4.4	88	24.7	22	6.3	206
2	57.6	97.1	324.6	0.32	97.2	218.7	16418.6	443.1	12.9	4.1	61	22.6	21	6.5	206
3	21.2	95.2	324.0	0.26	94.8	219.2	6037.9	317.7	12.4	5.0	41	29.1	22	6.2	204
4	37.3	96.4	324.6	0.36	95.7	218.3	10622.4	371.9	13.0	4.1	42	22.6	22	6.2	206
5	64.9	97.9	325.1	0.43	98.0	217.0	18502.4	465.4	13.0	4.0	48	21.9	21	6.7	206
6	73.3	97.9	324.9	0.46	98.0	216.4	20897.4	480.9	13.2	3.9	36	21.3	21	16	204
7	82.6	98.8	325.3	0.47	99.6	216.1	23540.3	513.5	13.2	3.7	30	19.9	22	17	205
8	98.2	100.2	326.0	0.55	100.9	217.2	27992.8	542.2	13.8	3.2	32	16.8	22	18	204

A - ppm - parts per million by volume

APPENDIX H

SUMMARY TABLES OF EMISSION TESTS RESULTS

TABLE H-1

SUMMARY OF PARTICULATE EMISSIONS DURING PRE LONG TERM NEAT OIL TESTS

[illegible]	DATE	TIME	% STEAM LOAD	ISOKINETIC %	SAMPLE VOLUME DSCF	STACK GAS FLOW RATE ACFM	STACK GAS FLOW RATE DSCFM	FLUE GAS % MOISTURE	FLUE GAS TEMP. ^oF	AVERAGE ORSAT % O_2 (DRY)	Fd $\frac{DSCF}{10^6 BTU}$	lb/DSCF	lb/10^6 BTU
[illegible]	9/10/80	1030-1330	35.4	108	27.6	4420	2500	11.99	366	4.5	9406.9	$7.01x10^{-6}$	0.0840
[illegible]a	9/10/80	1430-1[illegible]30	31.4	102	43.4	7260	4220	12.15	341	5.3		$3.97x10^{-6}$	0.0500
[illegible]b	9/10/80	1535-1835	31.4	108	43.1	6750	3920	12.52	339	4.7		$4.23x10^{-6}$	0.0513
4a	9/11/80	1336-1700	32.8	113	69.9	10400	6130	10.43	345	5.1		$5.39x10^{-6}$	0.0671
[illegible]b	9/11/80	1415-1715	32.8	106	46.2	7530	4260	14.39	344	5.1		$6.4 x10^{-6}$	0.0779
5a	9/12/80	0900-1[illegible]	95.6	108	91.5	18000	8370	12.50	545	4.3		$11.5x10^{-6}$	0.136
5b	9/12/80	0930-1216	95.6	105	88.8	17800	8270	12.53	542	4.3		$10.1x10^{-6}$	0.120
6a	9/12/80	1340-1640	97.8	105	91.7	18500	8630	11.82	545	3.6		$9.64x10^{-6}$	0.110
6b	9/12/80	1400-1700	97.8	106	85.2	16900	7900	12.11	544	3.6		$8.87x10^{-6}$	0.101
7	9/15/80	0925-1300	94.8	108	70.3	14000	6450	11.76	549	3.4		$12.4x10^{-6}$	0.139

TABLE H-2

SUMMARY OF NITROGEN OXIDE EMISSIONS FOR BOILER NO. 3 DURING PRE LONG TERM NEAT OIL TESTS

TEST NO.	DATE	TIME	% STEAM LOAD	AVG. NO_x AS NO (ppm)	AVG. NO_x AS NO (lb/DSCF)	AVG. NO_x AS NO_2 (lb/DSCF)	AVERAGE ORSAT % O_2 (DRY)	Fd DSCF/10^6 BTU	NO_x AS NO_2 lb/10^6 BTU
1a	9/9/80	1255-1355	36.8	136	1.06×10^{-5}	1.62×10^{-5}	5.1	9406.9	0.201
1b	9/9/80	1355-1635	36.8	124	9.62×10^{-6}	1.47×10^{-5}	5.8		0.192
2a	9/10/80	0930-1130	35.4	106	8.22×10^{-6}	1.26×10^{-5}	4.1		0.148
2b	9/10/80	1130-1330	35.4	128	9.93×10^{-6}	1.52×10^{-5}	4.7		0.185
3a	9/10/80	1430-1600	31.4	120	9.31×10^{-6}	1.43×10^{-5}	5.4		0.181
3b	9/10/80	1600-1830	31.4	120	9.31×10^{-6}	1.43×10^{-5}	4.8		0.174
4a	9/11/80	1330-1430	32.8	91	7.06×10^{-6}	1.08×10^{-5}	5.4		0.137
4b	9/11/80	1430-1530	32.8	97	7.52×10^{-6}	1.15×10^{-5}	6.2		0.154
5a	9/12/80	0830-1100	95.6	171	1.33×10^{-5}	2.03×10^{-5}	4.4		0.242
5b	9/12/80	1100-1330	95.6	165	1.28×10^{-5}	1.96×10^{-5}	4.3		0.232
6a	9/12/80	1330-1530	97.8	154	1.19×10^{-5}	1.83×10^{-5}	3.6		0.208
6b	9/12/80	1530-1720	97.8	135	1.05×10^{-5}	1.61×10^{-5}	3.6		0.183
7a	9/15/80	0830-1000	94.8	178	1.38×10^{-5}	2.12×10^{-5}	3.4		0.238
7b	9/15/80	1000-1200	94.8	142	1.10×10^{-5}	1.69×10^{-5}	3.4		0.190

TABLE H-3

SUMMARY OF PARTICULATE EMISSIONS DURING POST LONG TERM NEAT OIL TESTS

TEST NO.	DATE	TIME	% STEAM LOAD	ISOKINETIC %	SAMPLE VOLUME DSCF	STACK GAS FLOW RATE ACFM	STACK GAS FLOW RATE DSCFM	FLUE GAS % MOISTURE	FLUE GAS TEMP. °F	AVERAGE ORSAT % O_2 (DRY)	Fd $\frac{DSCF}{10^6 BTU}$	lb/DSCF	lb/10^6 BTU
2a	5/5/81	0900-1200	39.8	98.1	57.1	11053	5906	11.86	410	6.2	9272	2.07×10^6	0.0273
2b	5/5/81	1035-1330	39.8	104.1	48.6	10350	5553	11.35	412	6.2		3.63×10^6	0.0479
3a	5/5/81	1435-1730	40.4	106.5	51.8	9212	4939	11.37	411	6.1		9.99×10^6	0.131*
3b	5/5/81	1525-1800	40.4	106.0	46.7	10250	5508	11.19	411	6.1		2.53×10^6	0.0332
4a	5/6/81	0821-1116	110.9	102.0	91.8	22600	9140	11.60	679	5.1		5.11×10^6	0.0626
4b	5/6/81	0920-1210	110.9	93.1	84.3	20000	9190	12.20	680	5.1		5.66×10^6	0.0694
5a	5/6/81	1330-1630	99.4	101.4	75.3	18000	7540	14.70	606	3.3		4.30×10^6	0.0474
5b	5/6/81	1430-1715	99.4	103.3	77.8	17800	7640	12.0	606	3.3		4.32×10^6	0.0476
6a	5/7/81	0900-1145	108.1	102.3	100.7	23100	9990	10.70	642	4.1		3.73×10^6	0.0430
6b	5/7/81	0950-1250	108.1	105.6	92.7	20700	8910	11.20	640	4.1		4.24×10^6	0.0489

* Test 3a particulate data not believable based on disagreement with results of four (4) other tests run at essentially the same load. Questionable results believed to be due to pick-up of particulate from duct floor during test. Results not used in data analysis.

TABLE H-4

SUMMARY OF NITROGEN OXIDE EMISSIONS DURING POST LONG TERM NEAT OIL TESTS

TEST NO.	DATE	TIME	% STEAM LOAD	AVG. NO_x AS NO (ppm)	AVG. NO_x AS NO (lb/DSCF)	AVG. NO_x AS NO_2 (lb/DSCF)	AVERAGE ORSAT % O_2 (DRY)	Fd DSCF/10^6 BTU	NO_x AS NO_2 lb/10^6 BTU
1	5/4/81	1500-1530	39.1	93	7.24×10^{-6}	11.1×10^{-6}	7.1	9272	0.156
2a	5/5/81	0900-1115	39.8	99	7.71×10^{-6}	11.8×10^{-6}	6.2		0.155
2b	5/5/81	1115-1330	39.8	96	7.47×10^{-6}	11.4×10^{-6}	6.2		0.150
3a	5/5/81	1435-1545	40.4	95	7.40×10^{-6}	11.3×10^{-6}	6.1		0.148
3b	5/5/81	1545-1800	40.4	100	7.78×10^{-6}	11.9×10^{-6}	6.1		0.156
4a	5/6/81	0821-1030	110.9	160	12.4×10^{-6}	19.0×10^{-6}	5.1		0.233
4b	5/6/81	1030-1210	110.9	160	12.4×10^{-6}	19.0×10^{-6}	5.1		0.233
5a	5/6/81	1330-1500	99.4	145	11.3×10^{-6}	17.3×10^{-6}	3.3		0.190
5b	5/6/81	1500-1715	99.4	150	11.7×10^{-6}	17.9×10^{-6}	3.[illegible]		0.197
6a	5/7/81	0900-1110	108.1	148	11.5×10^{-6}	17.6×10^{-6}	4.1		0.203
6b	5/7/81	1110-1250	108.1	150	11.7×10^{-6}	17.9×10^{-6}	4.1		0.206

TABLE H-5

SUMMARY OF PARTICULATE EMISSIONS DURING PRE LONG TERM EMULSIFIED OIL TESTS

TEST NO.	DATE	TIME	% STEAM LOAD	ISOKINETIC %	SAMPLE VOLUME DSCF	STACK GAS FLOW RATE ACFM	STACK GAS FLOW RATE DSCFM	FLUE GAS % MOISTURE	FLUE GAS TEMP. °F	AVERAGE ORSAT % O_2 (DRY)	Fd $\frac{DSCF}{10^6 BTU}$	lb/DSCF	lb/10^6 BTU
2	6/22/81	1329-1558	41.4	104	45.2	7880	4310	12.1	377	4.4	9369	2.24×10^{-6}	0.0266
3a	6/23/81	0752-1055	40.5	105	52.2	9080	4970	12.1	381	5.2	↓	16.1×10^{-6}	0.201*
3b	6/23/81	0850-1150	40.5	105	39.8	6920	3840	11.1	382	5.2	↓	2.28×10^{-6}	0.0285
4a	6/23/81	1256-1549	40.3	105	47.8	8270	4570	12.1	377	5.0	↓	2.16×10^{-6}	0.0232
4b	6/23/81	1353-1700	40.3	105	44.1	7750	4300	11.7	378	5.0	↓	1.88×10^{-6}	0.0266
5a	6/24/81	0810-1059	103.8	100	92.4	20200	9220	11.2	574	4.5	↓	2.49×10^{-6}	0.0297
5b	6/24/81	0905-1154	103.8	101	90.1	20000	9090	11.0	581	4.7	↓	2.47×10^{-6}	0.0299
6a	6/24/81	1333-1610	96.6	102	81.9	16600	7990	11.8	540	4.1	↓	2.64×10^{-6}	0.0316
6b	6/24/81	1431-1705	96.6	104	76.2	16100	7460	12.1	545	4.0	↓	2.56×10^{-6}	0.0297
7a	6/25/81	0813-1048	96.8	103	82.4	17600	7990	12.8	554	4.1	↓	2.36×10^{-6}	0.0275

* Test 3a particulate data not believable based on disagreement with results of four (4) other tests run at essentially the same load. Questionable results believed to be due to pick-up of particulate from duct floor during test. Results not used in statistical analysis.

TABLE H-6

SUMMARY OF NITROGEN OXIDE EMISSIONS DURING PRE LONG TERM EMULSIFIED OIL TESTS

TEST NO.	DATE	TIME	% STEAM LOAD	AVG. NO_x AS NO (ppm)	AVG. NO_x AS NO (lb/DSCF)	AVG. NO_x AS NO_2 (lb/DSCF)	AVERAGE ORSAT % O_2 (DRY)	Fd DSCF/10^6 BTU	NO_x AS NO_2 lb/10^6 BTU
2a	6/22/81	1330-1430	41.4	82	6.4×10^{-6}	9.7×10^{-6}	4.5	9369	0.116
2b	5/22/81	1430-1600	41.4	80	6.2×10^{-6}	9.5×10^{-6}	4.3		0.119
3a	6/23/81	0752-1055	40.5	79	6.1×10^{-6}	9.4×10^{-6}	5.2		0.117
3b	6/23/81	1050-1150	40.5	80	6.2×10^{-6}	9.5×10^{-6}	5.2		0.119
4a	6/23/81	1256-1549	40.3	91	7.1×10^{-6}	10.8×10^{-6}	5.0		0.133
4b	6/23/81	1353-1700	40.3	93	7.2×10^{-6}	11.1×10^{-6}	5.0		0.137
5a	6/24/81	0810-1059	103.8	135	10.5×10^{-6}	16.1×10^{-6}	4.5		0.192
5b	6/24/81	0905-1154	103.8	135	10.5×10^{-6}	16.1×10^{-6}	4.7		0.195
6a	6/24/81	1333-1610	96.6	130	10.1×10^{-6}	15.5×10^{-6}	4.1		0.181
6b	6/24/81	1431-1705	96.6	130	10.1×10^{-6}	15.5×10^{-6}	4.0		0.180
7a	6/25/81	0810-0940	96.8	125	9.7×10^{-6}	14.9×10^{-6}	4.1		0.140
7b	6/25/81	0940-1100	96.8	127	9.8×10^{-6}	15.1×10^{-6}	4.1		0.176

TABLE H-7

SUMMARY OF PARTICULATE EMISSIONS DURING POST LONG TERM EMULSIFIED OIL TESTS

TEST NO.	DATE	TIME	% STEAM LOAD	ISOKINETIC %	SAMPLE VOLUME DSCF	STACK GAS FLOW RATE ACFM	STACK GAS FLOW RATE DSCFM	FLUE GAS % MOISTURE	FLUE GAS TEMP. °F	AVERAGE ORSAT % O_2 (DRY)	Fd $\frac{DSCF}{10^6 BTU}$	lb/DSCF	lb/10^6 BTU
1	3/22/82	1355-1600	102.4	104	38.7	21800	9723	10.8	589	3.9	9205	6.61×10^{-6}	0.0748
2a	3/23/82	0815-1025	99.9	107	37.1	20004	9113	10.3	583	4.2		30.9×10^{-6}	0.356*
2b	3/23/82	0905-1045	99.9	108	36.0	19445	8723	11.0	591	4.2		5.09×10^{-6}	0.0586
3a	3/23/82	1245-1450	96.7	105	35.9	19771	9044	12.4	556	2.8		5.75×10^{-6}	0.0610
3b	3/23/82	1330-1535	96.7	107	34.3	18316	8342	12.5	557	2.8		6.69×10^{-6}	0.0710
4a	3/24/82	0730-1040	34.7	105	53.5	5378	3137	12.6	339	4.5		4.57×10^{-6}	0.0536
4b	3/24/82	0900-1125	34.7	103	60.0	5794	3367	12.6	342	4.5		4.80×10^{-6}	0.0564
5a	3/24/82	1325-1530	34.1	103	33.2	5241	3055	12.0	345	4.5		3.56×10^{-6}	0.0420
5b	3/24/82	1400-1605	34.1	102	43.3	6249	3658	12.0	342	4.5		3.95×10^{-6}	0.0463
6	3/25/82	0720-0900	34.6	104	37.1	5662	3290	12.2	343	4.6		[illegible].95×10^{-6}	0.0584

* Test 2a particulate data not believable based on disagreement with results of four (4) other tests run at essentially the same load. Questionable results believed to be due to pick-up of particulate from duct floor during test. Results not used in statistical analysis.

TABLE H-8

SUMMARY OF NITROGEN OXIDE EMISSIONS DURING POST LONG TERM EMULSIFIED OIL TESTS

TEST NO.	DATE	TIME	% STEAM LOAD	AVG. NO_x AS NO (ppm)	AVG. NO_x AS NO (lb/DSCF)	AVG. NO_x AS NO_2 (lb/DSCF)	AVERAGE ORSAT % O_2 (DRY)	Fd DSCF/10^6 BTU	NO_x AS NO_2 lb/10^6 BTU
1a	3/22/82	1315-1515	102.4	112	8.72×10^{-6}	1.34×10^{-5}	3.9	9205	0.152
1b	3/22/82	1515-1715	102.4	129	10.02×10^{-6}	1.54×10^{-5}	3.9		0.174
2a	3/23/82	0715-0915	99.9	132	10.28×10^{-6}	1.58×10^{-5}	4.2		0.182
2b	3/23/82	0915-1115	99.9	135	10.47×10^{-6}	1.61×10^{-5}	4.2		0.185
3a	3/23/82	1200-1400	96.7	138	10.67×10^{-6}	1.64×10^{-5}	2.8		0.174
3b	3/23/82	1400-1600	96.7	170	13.19×10^{-6}	2.02×10^{-5}	2.8		0.215
4a	3/24/82	0755-0955	34.7	70	5.41×10^{-6}	8.30×10^{-6}	4.5		0.097
4b	3/24/82	0955-1100	34.7	75	5.80×10^{-6}	8.89×10^{-6}	4.5		0.104
5a	3/24/82	1315-1515	34.1	77	5.99×10^{-6}	9.18×10^{-6}	4.5		0.108
5b	3/24/82	1515-1715	34.1	80	6.18×10^{-6}	9.48×10^{-6}	4.5		0.111
6a	3/25/82	0700-0900	34.6	73	5.69×10^{-6}	8.72×10^{-6}	4.3		0.101
6b	3/25/82	0900-1100	34.6	80	6.24×10^{-6}	9.56×10^{-6}	4.3		0.111

APPENDIX I

BOILER TUBE TEST WINDOWS AND GAS PATH DEPOSITS REPORTS

Engineering
• Materials
• Forensic
• Safety

277 North Quaker Lane
West Hartford, CT 06119
Telephone 203-236-5141

Irving W. Glater, P.E., C.S.P.

July 24, 1981

Seaworthy Engine Systems
36 Main Street
Essex, CT 06426

Attention: Mr. Reed Cass

Subject: Coast Guard Academy Test Program-
Evaluation of Boiler Tube Test Windows
And Gas Path Deposits

Gentlemen:

I have the following to report:

CHARACTERIZATION OF TEST WINDOWS:

BACKGROUND:

In a meeting at Bigelow Co. in New Haven, CT on 6/3/80 it was decided that the test windows would be sectioned from ASTM A 106 seamless carbon steel pipe for high temperature service. Three test windows were received, representing the pipes from which all the other test pieces were sectioned. One of the pieces was marked with a pink layout dye, while the other two were normal steel gray color (see figures 1 and 2). The following represents the results of tests to verify the compliance of the material to ASTM A 106:

METALLOGRAPHIC:

This test was performed first. Transverse slices were taken from each specimen, mounted, ground, polished and etched. It was seen immediately that the pink sample has a significantly different microstructure from the other two, which were identical - there was much less pearlite in the ferrite matrix. See figures 3 and 4.

HARDNESS:

A number of 5 kg Vickers hardness impressions were made on the polished metallographic samples. Again the discrepancy was clear. The pink sample averaged 93HV while the other two pieces were 130/133 HV.

CHEMISTRY:

Because the two gray samples were nearly identical in both microstructure and hardness, it was decided that only one would be sent out for chemistry, along with the pink sample. The results are appended to this report. Both samples are low on silicon content, but otherwise meet the requirements of ASTM A 106.

THICKNESS:

A number of measurements were taken optically on the polished metallographic cross section specimens, and micrometer caliper readings were taken on the remaining sample material. Average thickness readings are as follows:

pink - 0.117 inch
gray - 0.114 inch
gray - 0.113 inch

CONCLUSION:

It would seem that with the exception of the low Si content in their compositions all of the test window specimens meet the requirements of ASTM A 106. The significant difference in microstructure and hardness would lead to the conclusion that the pink sample was Grade A material (i.e. 48 ksi min. UTS), while the other two pieces were Grade B (i.e. 60 ksi min. UTS).

EXAMINATION OF TEST WINDOWS FROM FURNACE:

BACKGROUND:

Nine test windows were received for examination, numbered as follows: 1,2,3,7,8,9,10,11,12. Apparently they were removed from the boiler tubes by an oxy-acetylene cutting torch, since they exhibited severe melting damage and thermal distress (see figures 5 through 10). Further examination showed that when the windows were initially installed the reinforcement portion of the groove welds was removed by grinding, and in most instances at least some of the window surface was damaged by grinding on the adjacent weld.

DETAILS OF EXAMINATION:

All samples were carefully examined with a eye to finding the region of least melting and thermal damage. A metallographic specimen was cut from each. These specimens were mounted, ground, polished, etched and examined. Unfortunately the thermal distress from removal destroyed anything that might have been present of a significant metallographic nature. Average thicknesses were measured; however, any reduction in thickness likely was due to grinding rather than corrosion.

ANALYSES OF SCRAPINGS FROM BOILER TUBES:

COMMENTS:

The appended chemical analyses were performed on samples that were marked "#1" and "#14." In my viewpoint, the most significant difference between the samples is carbon content - almost an order of magnitude. The presence of significant amounts of aluminum and nickel is worthy of speculation, as to their sources.

Respectfully submitted,

Irving W. Glater

Irving W. Glater
Principal

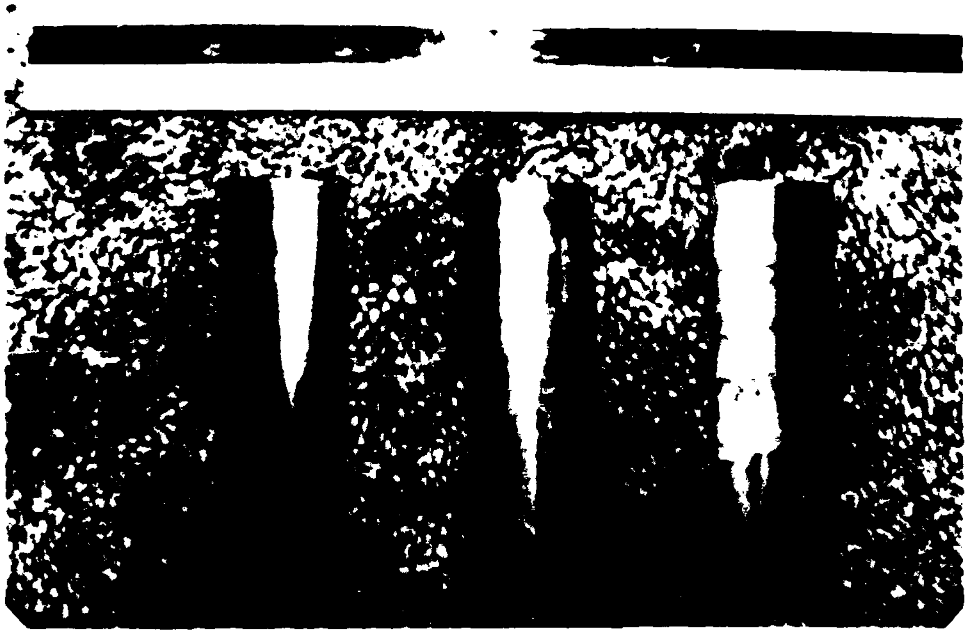


Figure 1 View of convex sides of test window samples. Note that specimen at left has pink layout dye on it.

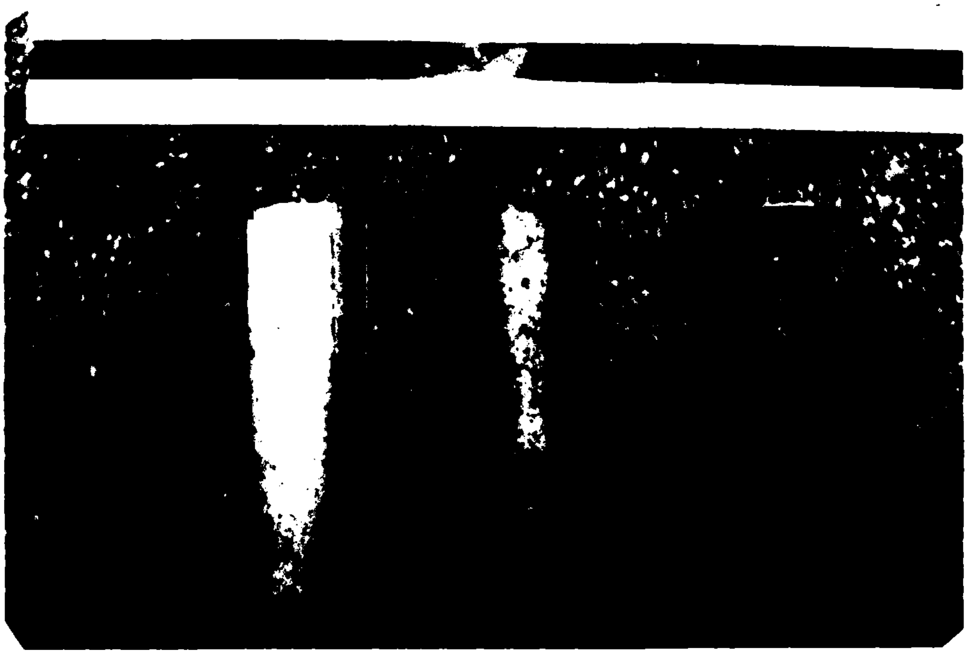


Figure 2 As above, except concave sides.

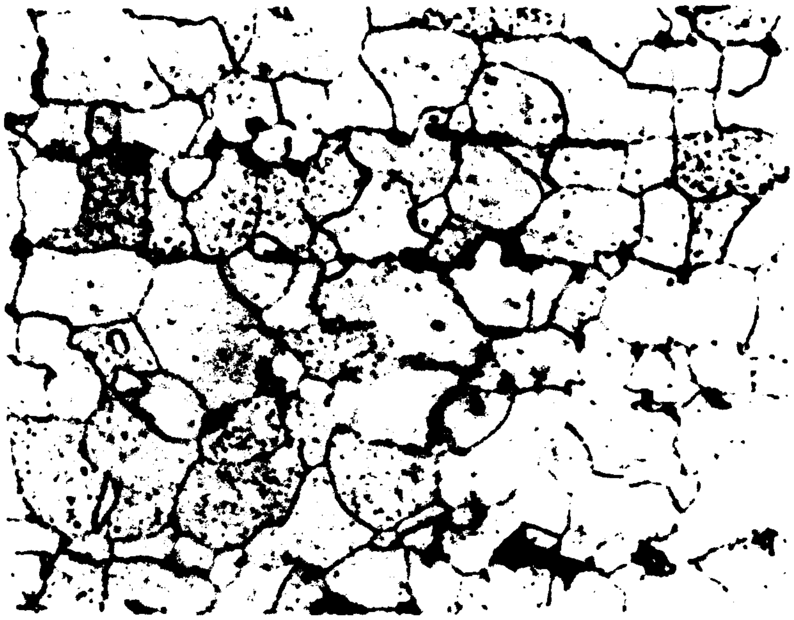


Figure 3 Microstructure of "pink" test window, consisting of primarily ferrite grains, with a few tiny pearlite islands (dark etching).
500X 2% Nital Etch

Figure 4 Microstructure typical of both other test windows. Much more pearlite (dark etching) is seen.
500X 2% Nital Etch

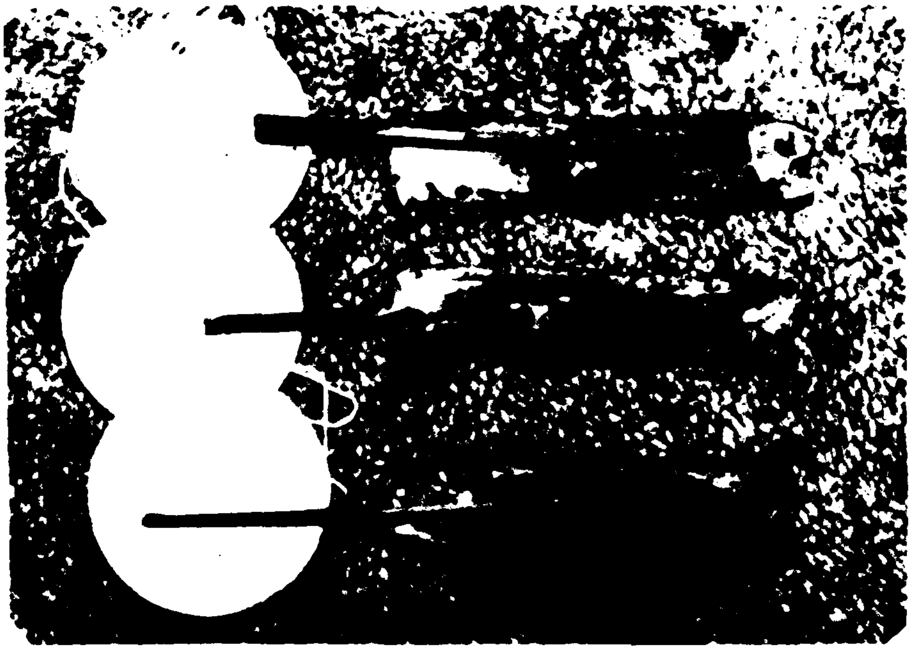


Figure 5 Convex sides of furnace specimens

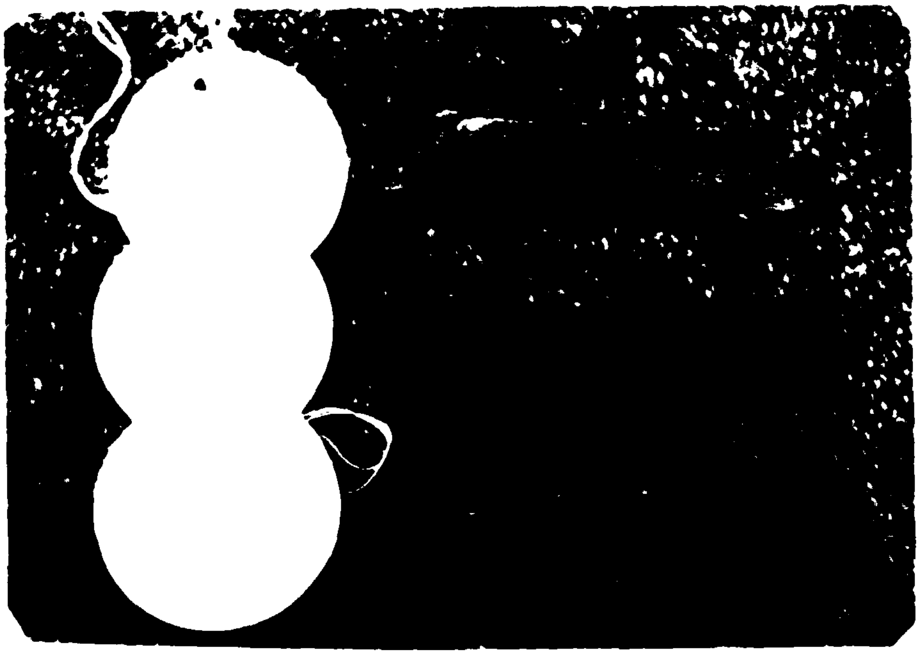


Figure 6 Concave sides of furnace specimens

Figure 7 Convex sides of furnace specimens

Figure 8 Concave sides of furnace specimens

Figure 9 Convex sides of furnace specimens

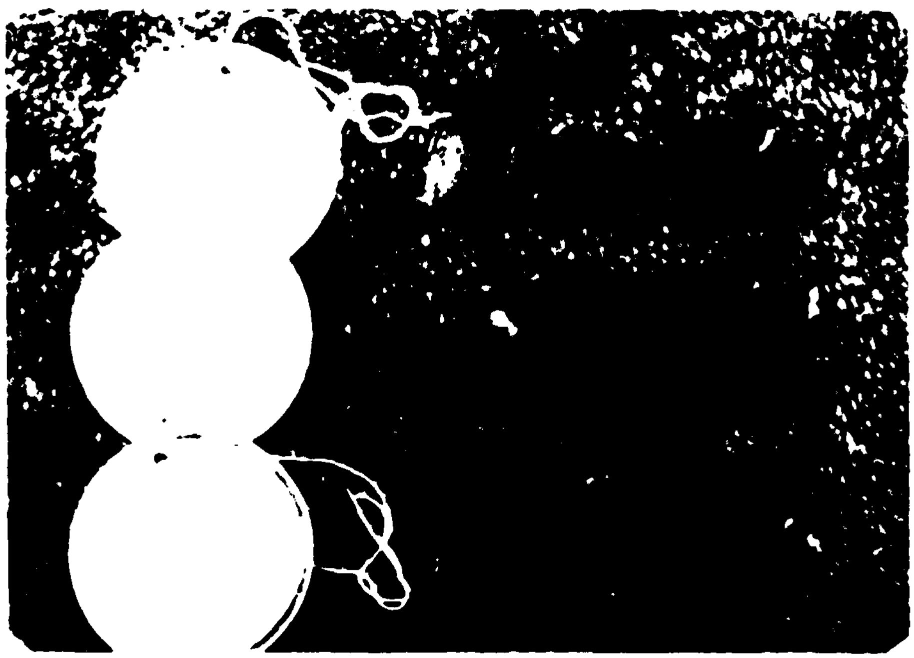


Figure 10 Concave sides of furnace specimens

The Henry Souther Engineering Co.

24 TOBEY ROAD, BLOOMFIELD, CONN. 06002
TEL. (203) 242-6291
ENGINEERS, METALLURGISTS and ANALYSTS

Irving W. Glater, P. E.
277 North Quaker Lane
West Hartford, CT. 06119

June 8/81

We have the following report to make on the sample received 6/4/81

Sample	Mark
675403-404	2 Samples - Boiler Scrapings - Marked #1 and #14

Chemical Analysis

	#1	#14
Carbon	5.45 %	50.66 %
Sulfur	10.05	5.87

Semi-quantitative spectrographic Analysis

	#1	#14	None detected
Sodium	Large amount	Small amount	Silver
Iron	Small amount	Large amount	Arsenic
Vanadium	Moderate amount	Moderate amount	Barium
Aluminum	Small amount	"	Bismuth
Nickel	"	"	Mercury
Silicon	"	Small amount	Indium
Calcium	Trace amount	"	Lithium
Magnesium	Small amount	"	Antimony
Molybdenum	"	Faint trace	Strontium
Copper	Faint trace	Trace amount	Tungsten
Cobalt	Faint trace	Trace amount	Zirconium
Potassium	Trace amount	Trace amount	
Lead	"	Faint trace	
Titanium	Faint trace	Trace amount	
Zinc	Trace amount	"	
Boron	None detected	Faint trace	
Chromium	"	"	
Manganese	"	"	
Cadmium	Faint trace	"	
Tin	"	"	

Key:		
Large amount	Greater Than	15 %
Moderate amount		5 - 15
Small amount		1 - 5
Trace amount		.1 - 1
Faint trace	Less than	0.1

F210A

Henry Souther Laboratories, Inc.

24 TOBEY ROAD, BLOOMFIELD, CONN. 06002
TEL. (203) 242-6291
ENGINEERS, METALLURGISTS and ANALYSTS

Irving W. Glater June 8/81

We have the following report to make upon the sample received 6/4/81

Sample	Mark
675403-404	2 Samples - Boiler Scrapings - Marked #1 and #14

Analysis

	#1 Tube Bank	#14 Tube Bank
Reaction	Neutral	Neutral

Qualitative Analysis

Chloride (Cl)	None detected	None detected
Carbonate (CO_3)	None detected	None detected
Sulfate (SO_4)	Present - large amount	Present - Moderate amount

Respectfully submitted,

HENRY SOUTHER LABORATORIES, INC.

Henry Souther Laboratories, Inc.

24 TOBEY ROAD, BLOOMFIELD, CONN. 06002
TEL. (203) 242-6291
ENGINEERS, METALLURGISTS and ANALYSTS

Irving W. Glater, P. E. 6/8/81
277 North Quaker Lane
West Hartford, CT. 06119

We have the following report to make upon the sample received 6/4/81

Sample	Mark
675402-A & B	(2) Samples - Carbon Steel

Chemical Analysis

	A - Pink	B - Grey
Carbon	.11 %	.15 %
Phosphorus	.014	.016
Sulfur	.015	.020
Manganese	.38	.35
Silicon	.08	.06

Respectfully submitted,

HENRY SOUTHER LABORATORIES, INC.

Engineering
• Materials
• Forensic
• Safety

277 North Quaker Lane
West Hartford, CT 06119
Telephone 203-236-5141

Irving W. Glater, P.E., C.S.P.

May 3, 1982

Seaworthy Engine Systems
36 Main Street
Essex, CT 06426

Attention: Mr. Reed Cass

Reference: Report (IWG), same subject, dated 7/24/81

Subject: Coast Guard Academy Test Program - Evaluation of Boiler Tube Test Windows and Gas Path Deposits.

Gentlemen:

I have the following to report:

BACKGROUND:

This report covers examination of a new set of metal and products of combustion samples which were exposed to or resulted from exposure to a different set of firing parameters than the samples whose examination was covered by the referenced report.

DETAILS OF EXAMINATION:

VISUAL:

The ID and OD surfaces of the test window specimens are seen in figures 1, 2 & 3. Note in figures 2 & 3 that the ID surfaces have precipitated, whitish salt deposits which are absent on the pieces in figure 1.

METALLOGRAPHIC:

Nine tube window specimens were received, numbered 2,3,4,7,8,9,10,11 &12. Transverse sections were cut from each and prepared for metallographic examination. It was determined that specimens 2 & 4 were made from the "pink" material of the referenced report, while the other seven specimens were made from the "gray" material. None of the

specimens showed any attack or distress on the fire side; however, all specimens showed a ferrous oxide layer approximately .0005 inch thick immediately on the parent metal, covered by a ferric oxide layer of varying thickness. On specimens 7,8,9,10,11&12 the thickness was fairly uniform at .0005 inch, while on specimens 2,3&4 the ferric material ranged up to .003 inch thickness (see figure 4). No evidence of significant metallurgical transformation (e.g. precipitation phenomena) was seen in any of the specimens.

HARDNESS:

A number of 5 kg Vickers hardness readings were taken on specimens representing the "pink" and "gray" material. The "gray" material averaged 133 HV, essentially the same as when it was unexposed. The "pink" material averaged 112HV, an increase over the unexposed average of 93 HV. It is suspected that the increase is due to a strain-aging phenomenon; however, it is unlikely to have any significant practical consequences.

CHEMICAL EXAMINATION OF DEPOSITS:

Four samples of powder or solid material resulting from the products of combustion were received for examination, as follows:

#1 - Slag on deck
#2 - Surface deposits on generating tubes
#3 - Deposits on back pass tubes
#4 - Scapings from tubes outlet damper

Samples 2,3&4 were subjected to semi-quantitative spectrographic analysis for metallic elements, quantitative analysis for carbon and sulfur, pH test, and qualitative analysis for Cl, SO_4 and CO_3 ions. Due to the vitreous nature of sample 1 it was decided that only the semi-quantitative analysis for metallic elements should be done.

The results of all tests are appended. The following observations are offered:

a. V, Ni, Al, Ca seem to be the predominant metallic elements; however, Ca is completely absent from the slag sample (#1). In the tests done in the referenced report Fe, Na, V were the predominant metallic elements.

b. The variation in carbon content among samples 2,3&4 is substantial.

Respectfully submitted,

Irving W. Slater

HENRY SOUTHER LABORATORIES, INC.

24 TOBEY ROAD, BLOOMFIELD, CONN. 06002
TEL. (203) 242-6291
ENGINEERS, METALLURGISTS and ANALYSTS

April 14, 1982

Irving Glater
277 North Quaker Lane
West Hartford, Conn. 06119

We have the following report to make upon the sample received 4/12/82

Sample	Mark
682036	Sample #1 Slag on Deck

Semi-quantitiative Spectrographic Analysis

		None Detected
Vanadium	Large Amount	Arsenic
		Boron
Nickel	Moderate Amount	Barium
		Bismuth
Aluminum	Small Amount	Calcium
Iron	" "	Mercury
Sodium	" "	Indium
Silicon	" "	Potassium
		Lithium
Cobalt	Trace Amount	Manganese
Copper	" "	Antimony
Phosphorus	" "	Strontium
Titanium	" "	Tungsten
Zinc	" "	Zirconium
Silver	Faint Trace	
Cadmium	" "	
Chromium	" "	
Magnesium	" "	
Molybdenum	" "	
Lead	" "	
Tin	" "	

KEY

Large Amount	more than	15%
Moderate	"	5-15
Small	"	1-5
Trace	"	0.1-1
Faint Trace	less than	.10

We certify that the above
is a true copy of our record.

HENRY SOUTHER LABORATORIES, INC.

F21A

HENRY SOUTHER LABORATORIES, INC.

24 TOBEY ROAD, BLOOMFIELD, CONN. 06002
TEL. (203) 242-6291
ENGINEERS, METALLURGISTS and ANALYSTS

April 16, 1982

Irving Glater
277 North Quaker Lane
West Hartford, Conn. 06119

We have the following report to make upon the sample received 4/12/82

Sample	Mark
682037	Sample #2 Surface deposits on generating tubes

Semi-quantitative Spectrographic Analysis

		None Detected
Vanadium	Large Amount	Silver
		Arsenic
Nickel	Moderate Amount	Boron
		Barium
Aluminum	Small Amount	Bismuth
Calcium	" "	Cadmium
Magnesium	" "	Chromium
Sodium	" "	Mercury
Silicon	" "	Indium
		Potassium
Cobalt	Trace Amount	Lithium
Copper	" "	Antimony
Iron	" "	Strontium
Molybdenum	" "	Tungsten
Lead	" "	Zirconium
Zinc	" "	
Manganese	Faint Trace	
Tin	" "	
Titanium	" "	

CHEMICAL ANALYSIS

Carbon	1.01%
Sulfur	11.65%

Reaction Neutral

Qualitative Analysis

Chloride	Joint Trace
Sulfate	Large Amount
Carbonate	None Detected

We certify that the above
is a true copy of our record.

HENRY SOUTHER LABORATORIES, INC.

Walter Solomon

F21A

HENRY SOUTHER LABORATORIES, INC.

24 TOBEY ROAD, BLOOMFIELD, CONN. 06002
TEL. (203) 242-6291
ENGINEERS, METALLURGISTS and ANALYSTS

April 16, 1982

Irving Glater
277 North Quaker Lane
West Hartford, Conn. 06119

We have the following report to make upon the sample received 4/12/82

Sample	Mark
682038	Sample #3 Deposits on back pass tubes

Semi-quantitative Spectrographic Analysis

		None Detected
Vanadium	Large Amount	Silver
		Arsenic
Nickel	Moderate Amount	Boron
		Barium
Aluminum	Small Amount	Bismuth
Calcium	" "	Cadmium
Magnesium	" "	Chromium
Sodium	" "	Mercury
Silicon	" "	Indium
Iron	" "	Potassium
		Lithium
Molybdenum	Trace Amount	Antimony
Cobalt	" "	Strontium
Copper	" "	Tungsten
Zinc	" "	Zirconium
Manganese	Faint Trace	
Lead	" "	
Tin	" "	
Titanium	" "	

CHEMICAL ANALYSIS

Carbon	15.60%
Sulfur	14.60%

Reaction Acidic

Qualitative Analysis

Chloride	Joint Trace
Sulfate	Large Amount
Carbonate	None Detected

We certify that the above
is a true copy of our record.

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HENRY SOUTHER LABORATORIES, INC.

24 TOBEY ROAD, BLOOMFIELD, CONN. 06002
TEL. (203) 242-6291
ENGINEERS, METALLURGISTS and ANALYSTS

April 16, 1982

Irving Glater
277 North Quaker Lane
West Hartford, Conn. 06119

We have the following report to make upon the sample received 4/12/82

Sample	Mark
682039	Sample #4 Boiler #3, Scrapings from tubes outlet damper

Semi-quantitative Spectrographic Analysis

		None Detected
Vanadium	Large Amount	Silver
		Arsenic
Calcium	Moderate Amount	Boron
Nickel	" "	Barium
		Bismuth
Aluminum	Small Amount	Cadmium
Iron	" "	Chromium
Magnesium	" "	Mercury
Silicon	" "	Indium
		Potassium
Cobalt	Trace Amount	Lithium
Copper	" "	Antimony
Sodium	" "	Strontium
Titanium	" "	Tungsten
		Zirconium
Manganese	Faint Trace	
Molybdenum	" "	
Lead	" "	
Tin	" "	
Zinc	" "	

CHEMICAL ANALYSIS

Carbon	46.36%
Sulfur	7.84

Reaction Neutral

Qualitative Analysis

Chloride	None Detected
Sulfate	Large Amount
Carbonate	None Detected

We certify that the above
is a true copy of our record.

HENRY SOUTHER LABORATORIES, INC.

P21A

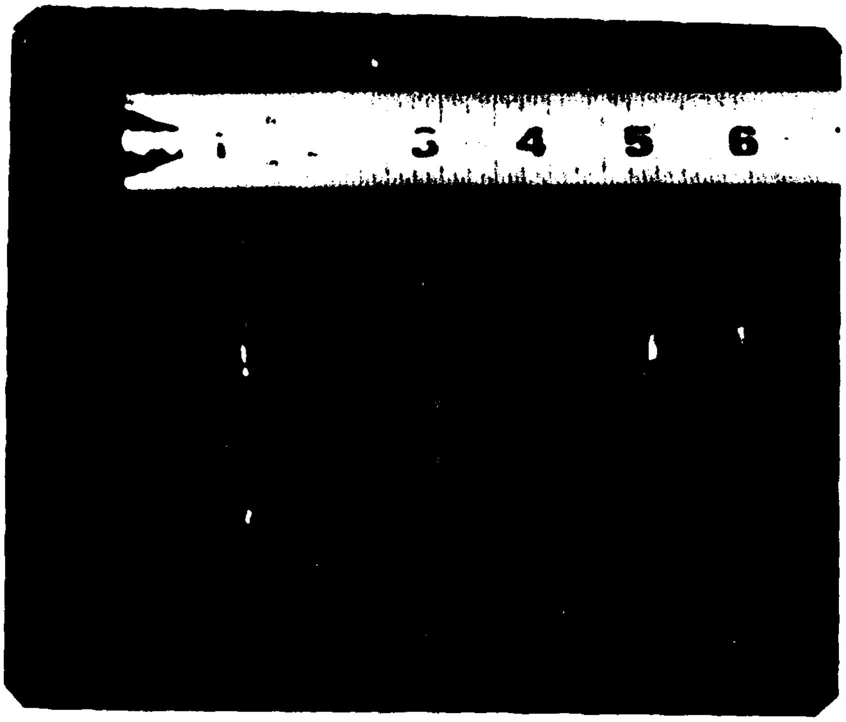
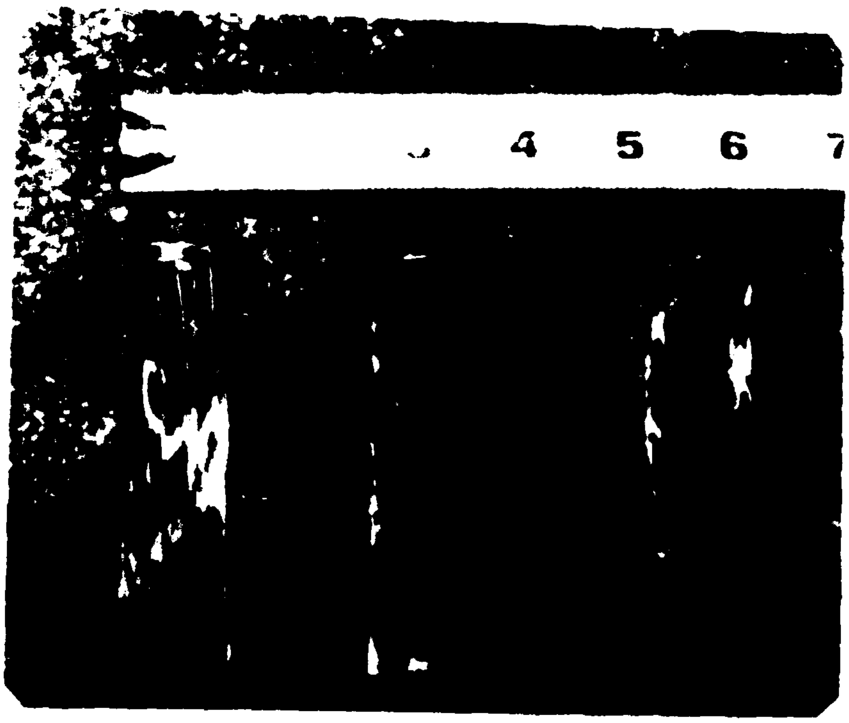


Figure 1 ID surfaces of test window samples (above)
OD surfaces of same samples (below)



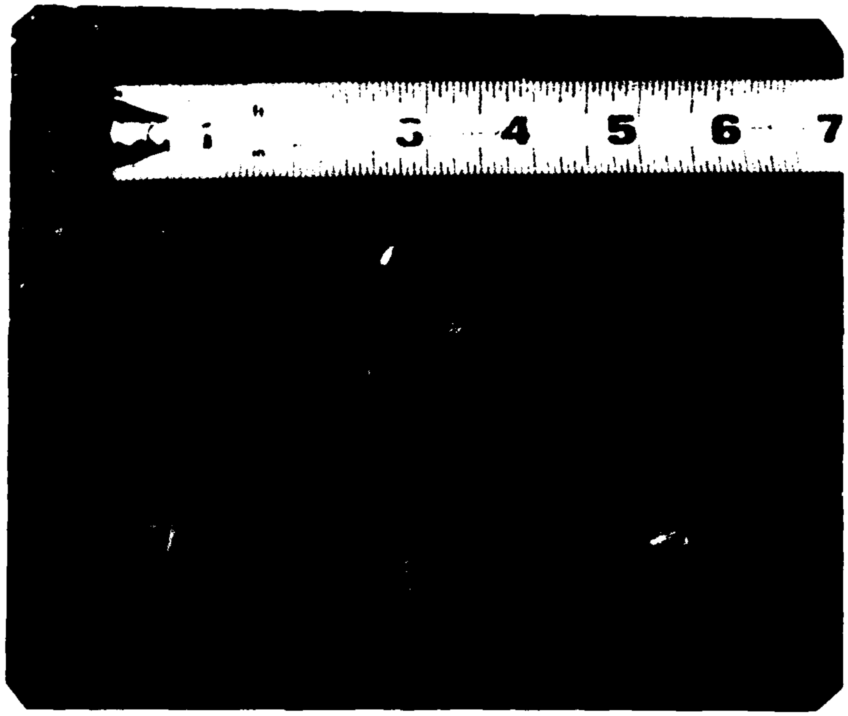


Figure 2 ID surfaces of test window samples (above)
OD surfaces of same samples (below)

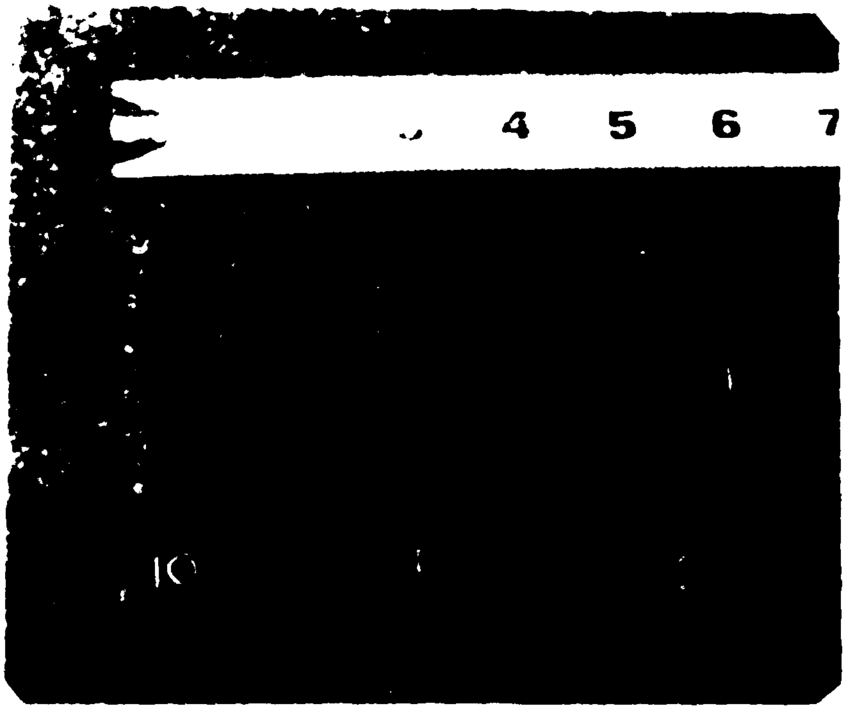


Figure 3 ID surfaces of test window samples (above)
OD surfaces of same samples (below)

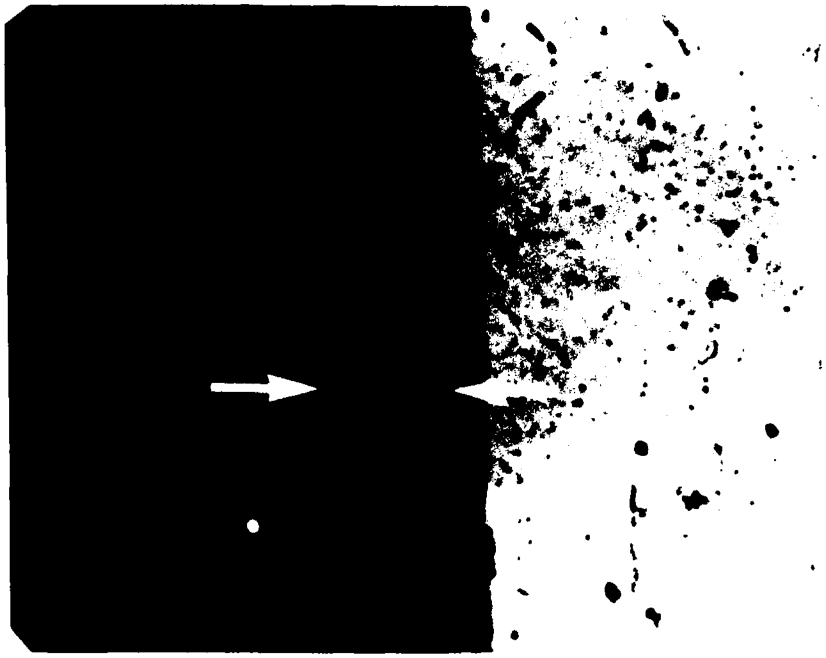


Figure 4 Tranverse section through ID on specimen #2. Hazy appearing material between arrows is ferric (red) oxide. Narrower band adjacent is ferrous (black) oxide. Light etching base metal is at right .
500X 2% Nital Etch

APPENDIX J

BOILER INSPECTION REPORTS

Seaworthy Engine Systems

BOILER INSPECTION REPORT
SES PROJECT 066-01

Date of Inspection 20-21 August/8 Sept., 1980 (Furnace Tubes)

Boiler No. 3

Location: USCG Academy, New London, CT

Inspector: RW Cass/JM MacDonald

Inspection Results:

Gas Side

Furnace Floor: Loosely sintered in the rear-half of floor, 30% cracks showing, castible refractory patch made in way of step joint, and in the middle of front-half of the floor, single brick side and rear corbell, no front corbell, rear corbell deterioriating slightly about 25%, no buckling. See photo of furnace floor.

Wall Refractory: Lower knee walls spalled and vitrified. 15% castible patch right side, 20% castible patch right, upper knee wall caps left/right sides, 100% patched. Walls spalled and vitrified, heavily midway into boiler. See photos of right & left knee walls.

Burner Refractory: Upper front wall good condition, 5% cracks showing. Burner throat tiles true and in good condition, lower front wall 25% glazed with light coking. See photos right and left burner throats.

Water Wall Tubes: Tubes cleaned to base metal with light coating of brown oxide due to recent steam cleaning but otherwise clean. See photos - right, left and rear water wall tubes.

Generating Tubes: Sintered deposits lower 25%, light coating water soluble soot. See photo of generating tubes.

Boiler Casing: Casing bolting and gasketing in good condition. Soot box below water drum clean.

Flue Gas Baffles: 1st & 2nd pass inspected - good condition, slight brick misalignment in rear corners of furnace baffles extending from knee wall to turn of roof tubes. See photos of lower and upper 1st pass baffle.

Flue Gas Damper: Two piece solid metal dampers - good condition, clean. See photo of flue gas damper.

Gas Side General Comments: Generally good condition, recently cleaned with wire brush, steam and chemicals.

Water Side

Steam Drum: Clean and flushed - no mineral (brown) deposits. Some mechanical loose scale specks. Slight oxidation of metal (light rust) 20%; 80% bare metal. Localized pitting at belt line, chemical feed line 18" long into left head of drum. See photo of steam drum.

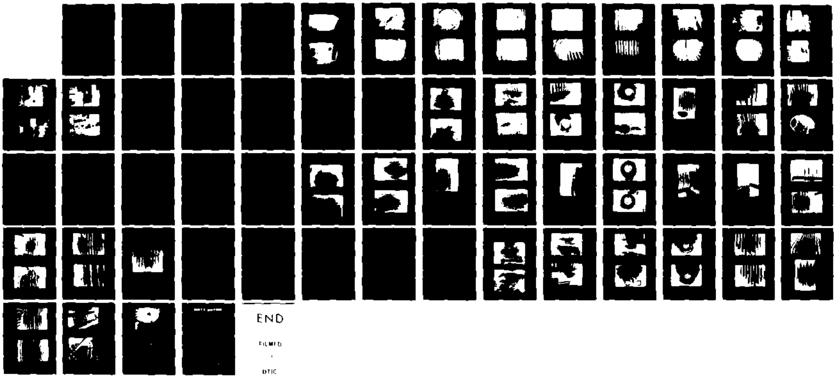
Water Drum: Cleaned and flushed - no mineral (brown) deposits. Small amount of hard mechanical loose scale. Slight oxidation of metal (light rust) 20%; 80% bare metal. See photo of water drum.

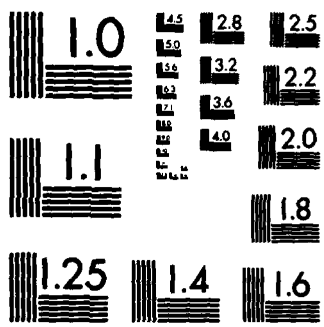
Water Wall Header: Clean, small particles of mechanical hard scale. Light oxidation.

Water Side General Comments: Normal physical appearance - recently cleaned and flushed, no mineral build-ups.

AD-A121 011 SHORESIDE BOILER DEMONSTRATION ...
(U) SEAWORTHY ENGINE SYSTEMS INC ESSEX CT
R W CASS ET AL. AUG 82 USCG-D-04-82 DTCG23-80-C-20001

UNCLASSIFIED F/G 21/4 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Fuel Oil System

Fuel Oil Pump: New gear pump installed 8/21/80, electric gear pump with steam recip back-up.

Fuel Oil Heater: Two (2) steam shell and tube heaters with electric back-up; Peabody - condition operational.

Burners and Sprayer Plates: Peabody; good condition, new tips and plugs for test available.

Burner Registers: Peabody; good condition, register tubes loose, diffuser lightly slagged, slots free. Mechanical linkage good. See photo of diffuser.

Fuel Oil Meter: New; Brookes meter for test, electric pulse signal and recorder. See photo fuel meter.

Fuel Oil Treatment System: Batch treatment - Nutmeg MCC sludge solvent, dosage ratio at present 4000 to 1.

Fuel Oil System General Comments: Normal operating condition; viscosity meter added to system. See photo viscosity meter.

Combustion Air

Forced Draft Blower: Combination electric with steam driven back-up, radial vane inlet control. Vanes, linkage & screens clean & free, inlet air temperature thermocouple on inlet screen. See photo combustion air thermocouple.

Air Damper: Radial vane integrated with combustion control. Secondary control with boiler gas outlet damper to uptake. Pneumatic servo control, two speed electric drive.

Combustion Control System

Fuel Oil/Combustion Air Ratio Controller: Hagan manual/auto master pressure control Δ P air fuel controller with Westinghouse 02 loop oxygen trim system. See photos of 02 trim system.

Feed Water System

Feed Water Pump: Electric driven horizontal centrifugal discharge 150 psig steam recip back-up.

Feed Water Regulator: Single stage, direct acting off of drum water level (gage glass, tri-cocks and low water level cut-outs fitted)

Feed Water Treatment System: Betz 716, 729, 733, 741 control for corrosion scale, sludge formation, iron control, anti-carry-over, flocculent properties.

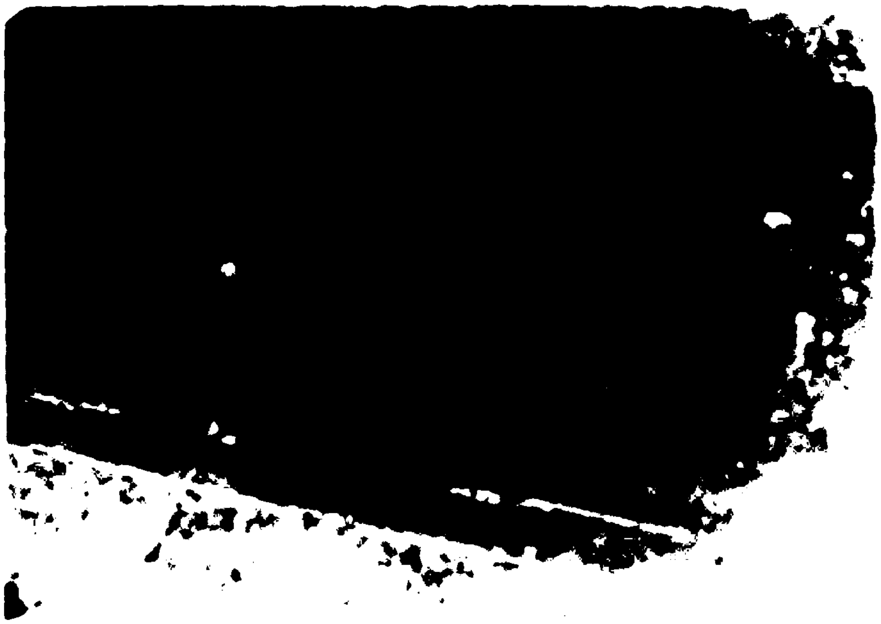
Feed Water Blowdown System: Surface, bottom and leg headers blows. Surface blows semi-automatic.

Feed Water Meter: New Hoffer-Flow high accuracy meter with remote readout. Feed water thermocouple with remote readout fitted. See photo of feed water meter.

Soot Blowing System

Soot Blowing Elements: Drum pressure desuperheated steam units (Copes Vulcan) three hand rotated chain driven elements, located in generating bank.

PHOTOGRAPHS OF BOILER NO. 3
AT U.S.C.G. ACADEMY, NEW LONDON, CT

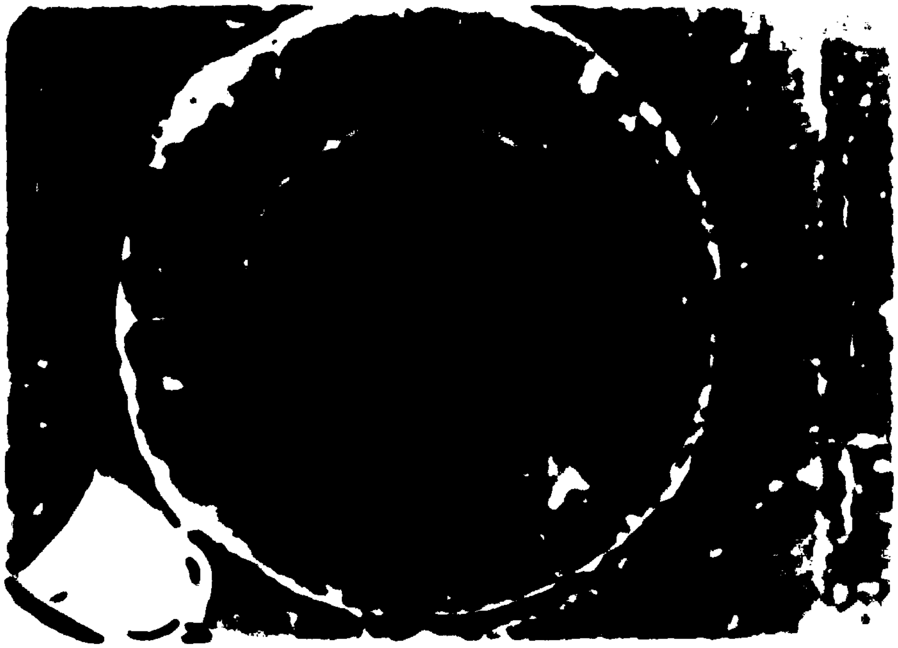


1. Furnace Floor Toward Rear Wall - 8/21/80

2. Left Furnace Knee Wall Towards Rear Wall - 8/21/80

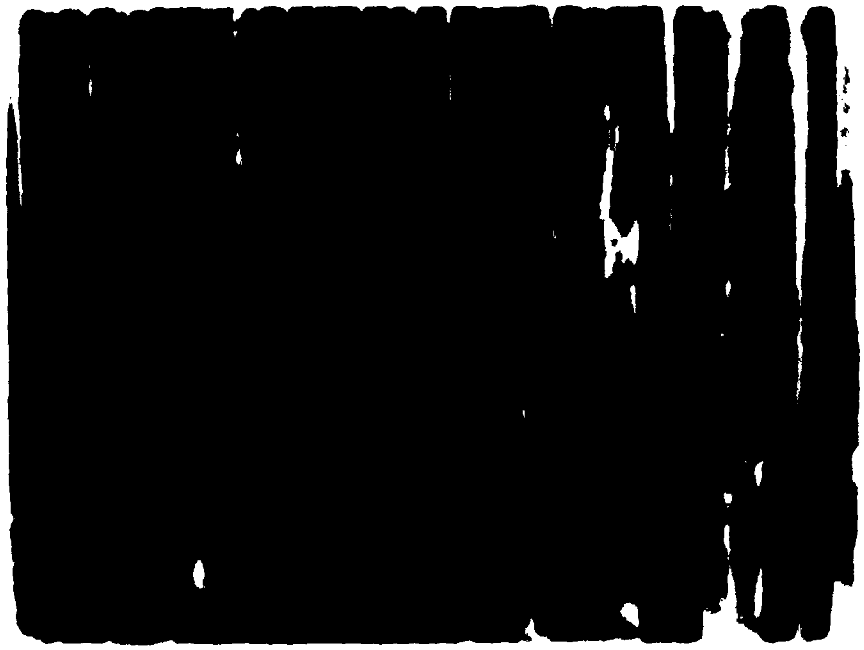
3. Right Furnace Knee Wall Toward Front Wall - 8/21/80

4. Right Burner Throat - 8/21/80



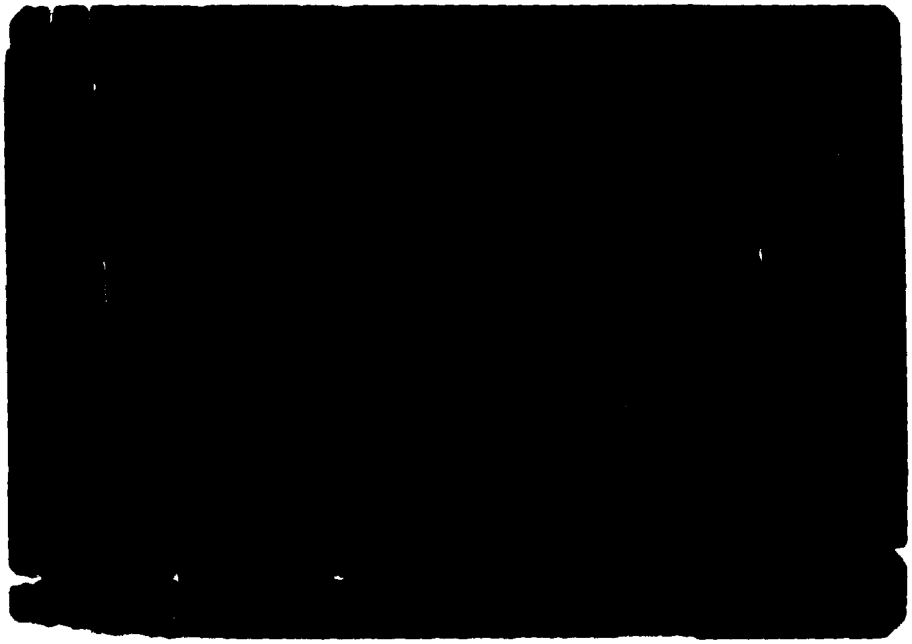
5. Left Burner Throat - 8/21/80

6. Right Water Wall Tubes Toward Boiler Front - 9/8/80



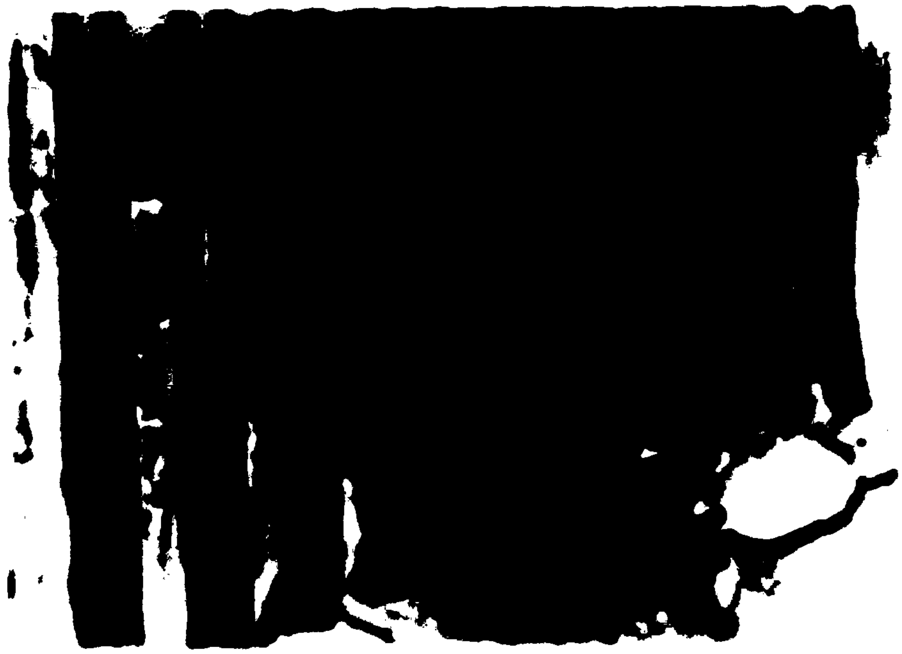
7. Right Water Wall Tubes Toward Boiler Rear - 9/8/80

8. Left Water Wall Tubes Toward Boiler Rear - 9/8/80



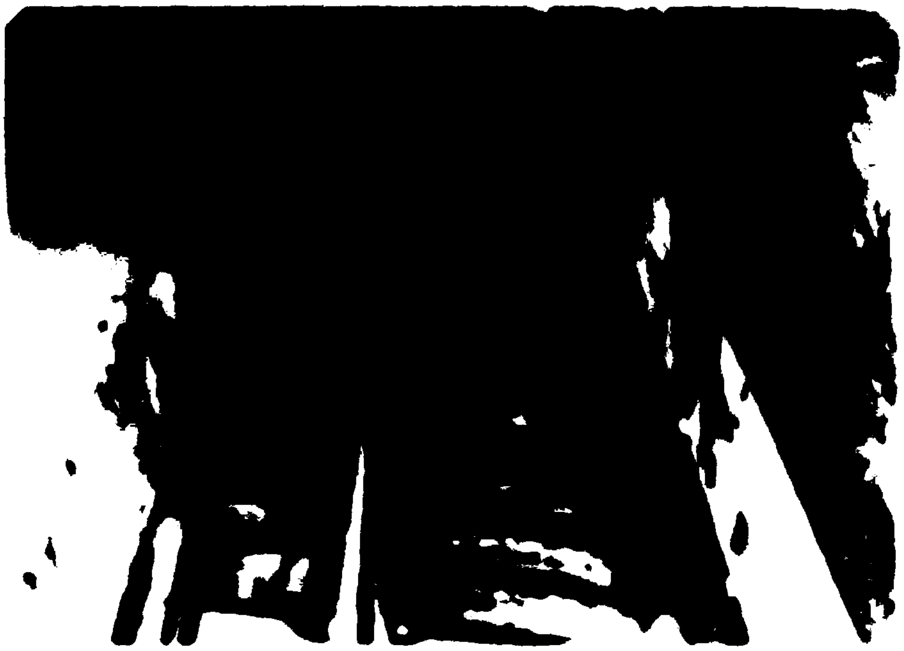
9. Rear Water Wall Tubes - 9/8/80

10. Generating Tubes in Furnace - 9/8/80

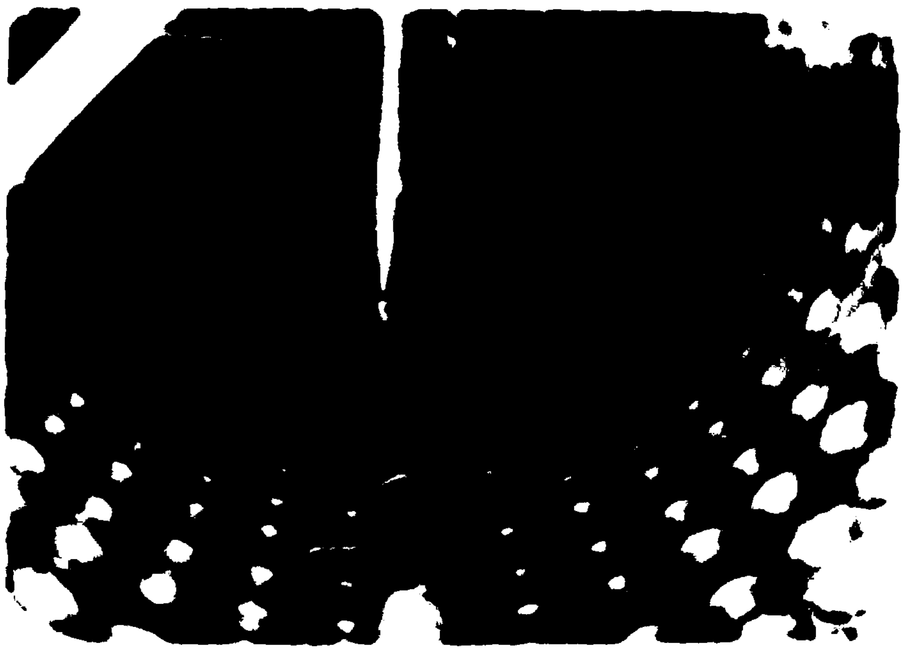


11. First Gas Pass Baffle, Lower - 8/21/80

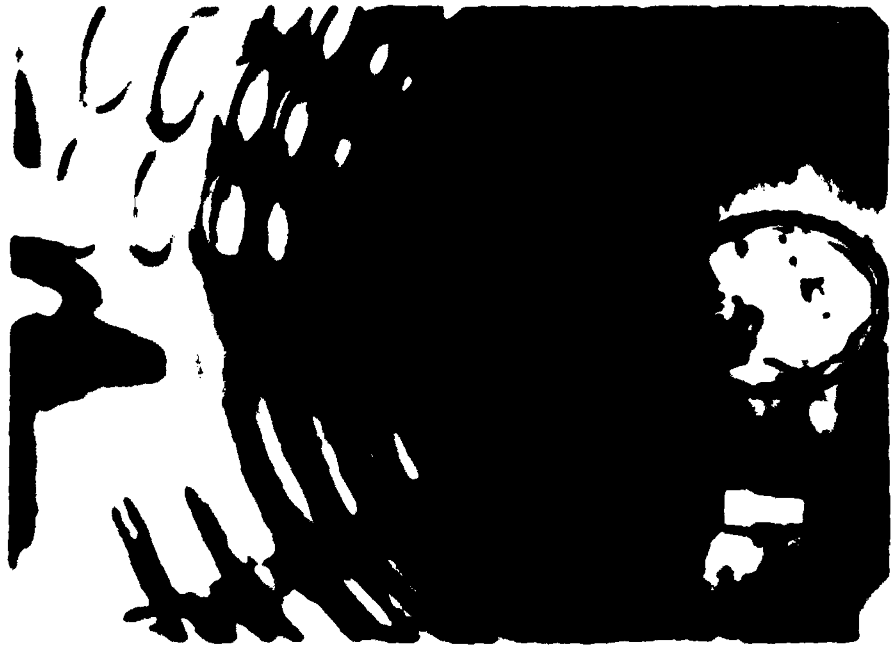
12. First Gas Pass Baffle, Upper - 8/21/80



13. Flue Gas Damper - 8/21/80

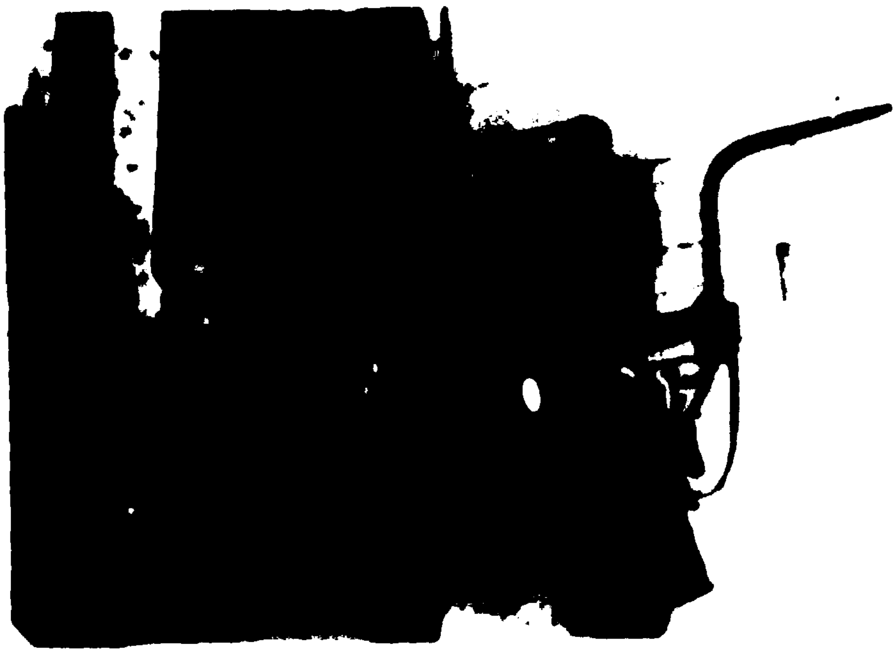


14. Steam Drum - 8/21/80

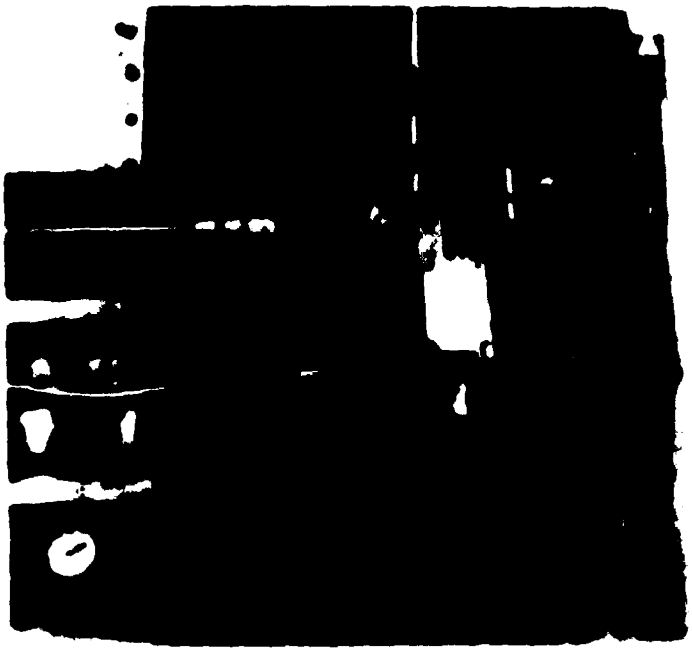


15. Water Drum - 8/21/80

16. Burner Diffuser - 8/21/80



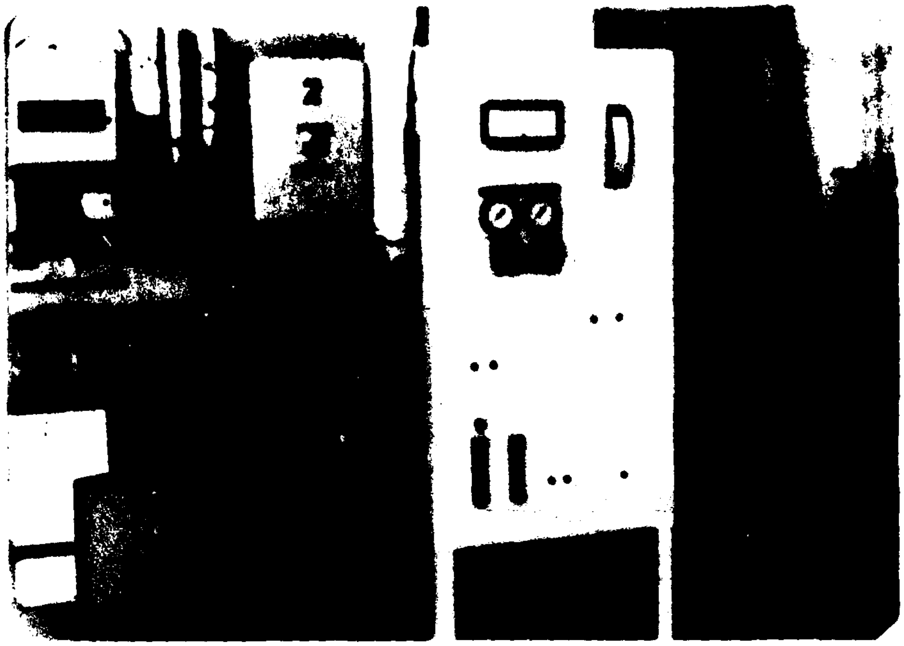
17. Fuel Oil Meter - 8/21/80



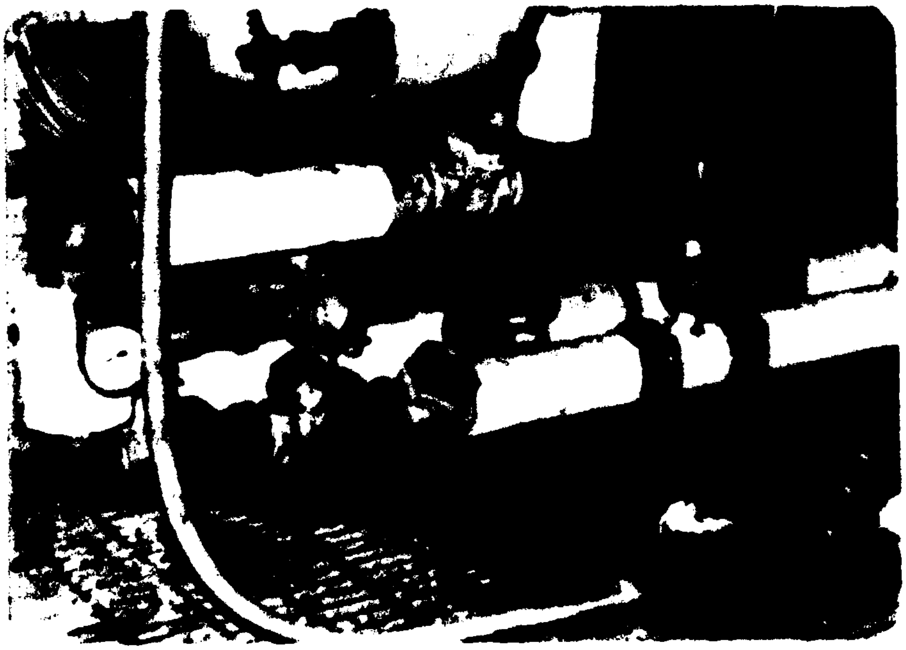
18. Fuel Oil Viscosity Meter - 8/21/80

19. Combustion Air Thermocouple - 8/21/80

20. Oxygen Sensor for 02 Trim System - 8/21/80



21. Control Panel for 02 Trim System - 8/21/80



22. Feed Water Meter - 8/21/80

Seaworthy Engine Systems

BOILER INSPECTION REPORT
SES PROJECT 066-01

Date of Inspection 5/15/81

Boiler No. 3

Location: USCG Academy, New London, CT

Inspector: R. Cass/P. Vollemans

Inspection Results:

Gas Side

Furnace Floor: Loose sintered refractory covering, cracks showning, loose brick in center step, flame impingement mark in front of left burner, before center step, brickwork and rubble from knee walls on floor. No buckling. See photos #1 and #2 of furnace floor.

Wall Refractory: Knee walls slagged and damaged. Specifically, right knee wall missing several brick, corbel cracked and separating from front wall. Left knee wall similiar condition as right knee wall plus evidence of flame impingement. Rear knee wall had heavy slagging and was missing sections of corbel. See photos #3, #4 & #5 of knee walls.

Burner Refractory: Burner throat tile true and in fair condition. Specifically right throat separating by flame eye. Left throat had one section (@ 1 o'clock) chipped and loose. See photos #6 & #7 of burner throats.

Water Wall Tubes: Entire furnace had 1/16" to 1/8" thick layer of brown powdery deposits which were easily scrapped off. Left water wall tubes had signs of flame impingement on the 8th through 13th tubes from the boiler front. See photos #8, #9 & #10 of the water wall tubes.

Generating Tubes: 1st bank of generating tubes had 1/16" to 1/8" thick layer of brown powdery deposits which were easily scrapped off. Other generating tubes had black sooty deposits which were of a maximum thickness of 1/8" to 1/4" by the gas damper. See photo #11.

Boiler Casing: Casing, bolting and gasketing in fair condition.

Flue Gas Baffles: First gas pass baffle in good condition. See photo #12. Last gas path baffle had void between 4th & 5th tube row from left side of boiler. Void was approximately 5" wide by 18" high. Void occured because of air pocket when baffle was poured.

Flue Gas Damper: Damper in good condition with minimal deposits.

Gas Side General Comments: Knee walls in need of replacement along with seal caps. Black sooty deposits and evidence of flame impingement indicate some incomplete combustion in furnace.

Water Side

Steam Drum: Thin (approximately 1/64"), soft, uniform layer of baked-on sludge which could easily be removed down to bare metal. See photo # 13.

Water Drum: Same as steam drum.

Water Wall Header: Same as steam drum.

Water Side General Comments: Internal waterside conditions were very good. Water hose cleaning only, required. No acid cleaning necessary. Normal water treatment sufficient to maintain clean surfaces.

Fuel Oil System

Fuel Oil Pump: Condition operational in need of periodic maintenance (seals).

Fuel Oil Heater: Condition operational.

Burners and Sprayer Plates: Fair condition with oil tubes lightly coked. Tips were new at beginning of long-term test and are in fair condition with miscellaneous scratches.

Burner Registers: Fair to poor condition. One register is sticky and difficult to open - in need of overhaul.

Fuel Oil Meter: Brooks ER Positive Displacement Oscillating Piston Meter, Model ER 11LHP with accuracy $\pm$ 0.5% of flowrate over range of 0.75-7 gpm.

Fuel Oil Treatment System: Batch treatment, Nutmeg NCC sludge solvent. Dosage ratio approximately 4000 to 1.

Fuel Oil System General Comments: Condition operational.

Combustion Air

Forced Draft Blower: Condition operational.

Air Damper: Condition operational in need of cleaning and lubrication.

Combustion Control System

Fuel Oil/Combustion Air Ratio Controller: Condition operational, however, in need of adjustment due to replacement of diaphrams in variable ratio regulator and fuel oil regulating valve.

Feed Water System

Feed Water Pump: Condition operational.

Feed Water Regulator: Condition operational.

Feed Water Treatment System: Betz 716, 729, 733, 741. Control for corrosion, scale, sludge formation, iron control, anti-carry over, flocculent properties.

Feed Water Blowdown System: System operational.

Feed Water Meter: Hoffer Model HO 1½x81 30SF, turbine meter with accuracy of ± 0.35% of actual reading.

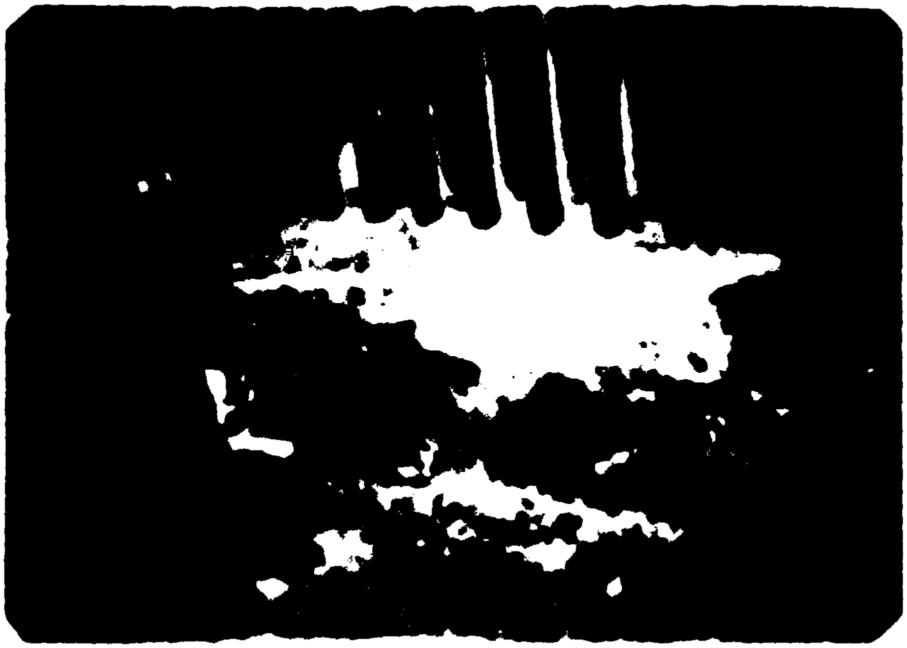
Soot Blowing System

Soot Blowing Elements: Condition operational.

PHOTOGRAPHS OF BOILER NO. 3
U.S.C.G. ACADEMY, NEW LONDON, CT

1. Furnace Floor Toward Rear Wall - 5/15/81

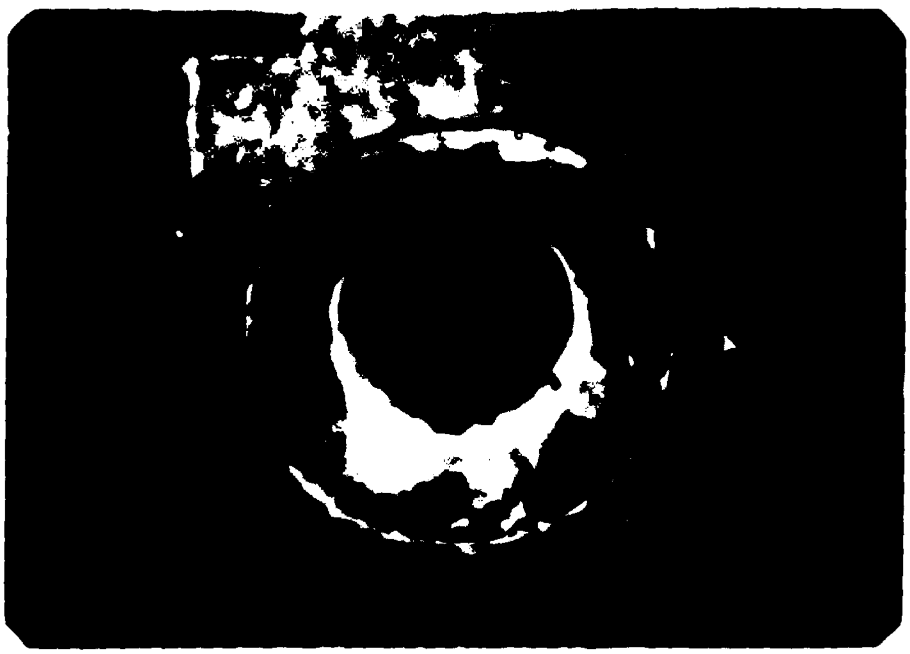
2. Furnace Floor Toward Front Wall - 5/15/81



3. Left Furnace Knee Wall Toward Front Wall - 5/15/81

4. Left Furnace Knee Wall Toward Rear Wall - 5/15/81

5. Right Furnace Knee Wall Toward Front Wall - 5/15/81



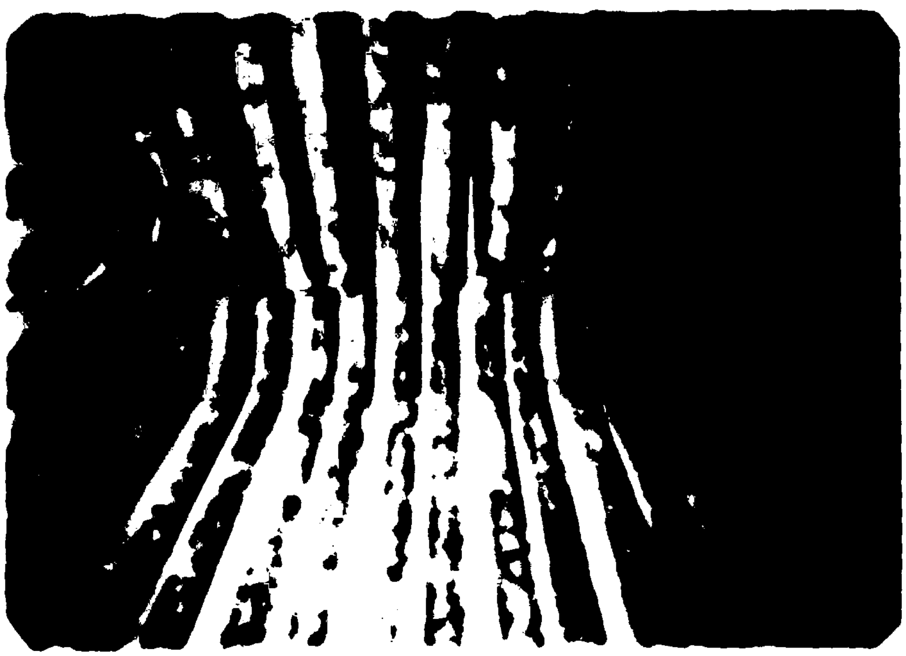
6. Right Burner Throat - 5/15/81

7. Left Burner Throat - 5/15/81

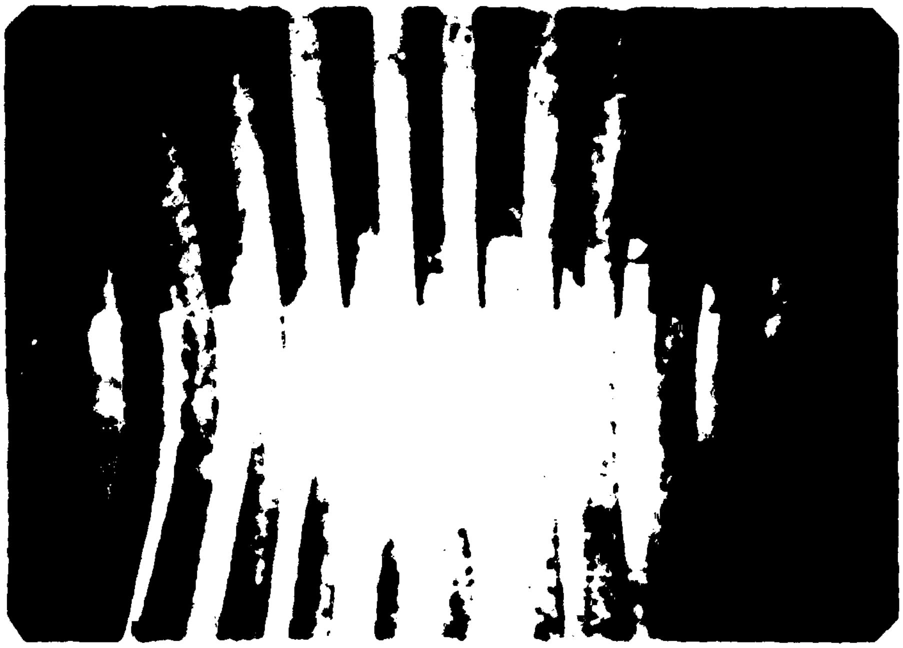
8. Right Rear Water Wall Tubes - 5/15/81

9. Rear Water Wall Tubes - 5/15/81

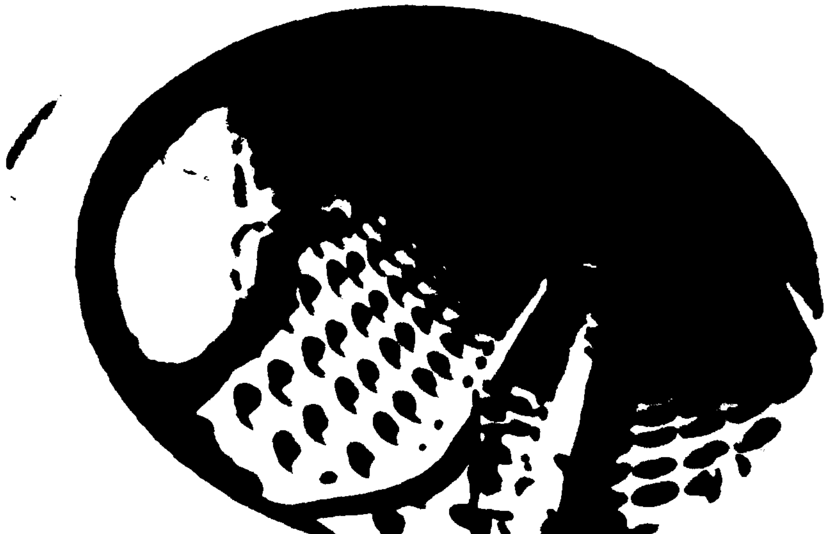
10. Left Water Wall Tubes - 5/15/81



11. Front Water Wall and Generating Tubes - 5/15/81



12. First Gas Pass Baffle - 5/15/81



13. Steam Drum From Feed Water Regulator End - 5/15/81

Seaworthy Engine Systems

BOILER INSPECTION REPORT
SES PROJECT 066-01

Date of Inspection: 6/3/81

Boiler No.: [illegible]

Location: USCG Academy, New London, CT

Inspector: [illegible] Cass

Inspection Results:

Fire Side

Furnace Floor: Floor cleaned, knee wall rubble removed. No repairs to Furnace Floor. See photos #1 and #2 of furnace floor.

Wall Refractory: Right and left knee walls rebuilt, seal caps on right left and rear knee walls replaced. See photos #3-8 of furnace walls.

Burner Refractory: Burner throats trued and resurfaced. See photos #9 and #10 of burner throats.

Water Wall Tubes: Water wall tubes cleaned to bare metal. See photos #11-16 of water wall tubes.

Generating Tubes: Generating tubes cleaned to bare metal. See photos #17 and #18 of generating tubes.

Boiler Casing: All spots where leaking was evident are sealed. All door gaskets renewed.

Flue Gas Baffles: ~~1st pass baffle in good condition. Hole~~ last past baffle filled. See photo #19

Flue Gas Damper: Damper clean with soot deposits removed.

Gas Side General Comments: Boiler gas side clean and returned to physical condition similiar to pre long term neat oil test.

Water Side

Steam Drum: Drum cleaned of sludge layer to bare metal.

Water Drum: Same as steam drum.

Water Wall Header: Same as steam drum.

Water Side General Comments: Internal water side clean and in a similiar condition to pre long term neat oil tests.

Fuel Oil System

Fuel Oil Pump: Replacement pump installed with correct seals. Previous pump internals are in good condition, the seal problem was due to improper seal installation by manufacturer.

Fuel Oil Heater: Condition operational - no change.

Burners and Sprayer Plates: Burners cleaned and new tips and plugs for emulsified oil tests.

Burner Registers: Both registers cleaned with new operating rings installed. Register #1 also has a new shaft and arm. Both registers operate freely.

Fuel Oil Meter: ~~Same as 5/15/81 Inspection Report.~~

Fuel Oil Treatment System: Same as 5/15/81 Inspection Report.

Fuel Oil System General Comments: System in good condition. Discharge strainer clean. Flexible lines from burner valves to burners replaced, burner valves replaced.

Combustion Air

Forced Draft Blower: Cleaned and lubricated.

Air Damper: Cleaned and lubricated (completely disassembled and reassembled).

Combustion Control System

Fuel Oil/Combustion Air Ratio Controller: New Hagan Master and Compensating relay adjusted by Hagan representative.

Feed Water System

Feed Water Pump: Condition operational

Feed Water Regulator: New valve disc and seat. All parts cleaned and worn parts replaced.

Feed Water Treatment System: Same as 5/15/81 Inspection Report.

Feed Water Blowdown System: System operational.

Feed Water Meter: Same as 5/15/81 Inspection Report.

Soot Blowing System

Soot Blowing Elements: Supply valve lapped in and tight. Soot blower rotation correct. No enlargement of holes or obstructions in holes. Elements cleaned and lubricated.

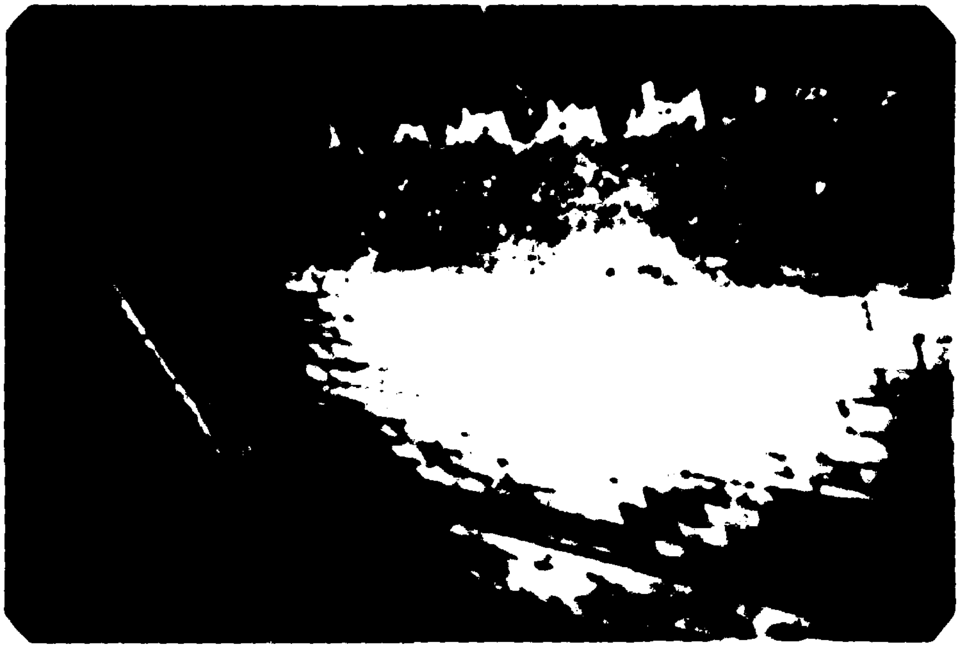
Steam Atomization System:

Steam atomizing regulator rebuilt with new diaphram. Steam trap added immediately upstream of regulating valve. New valves and flexible lines at burners.

PHOTOGRAPHS OF BOILER NO. 3
AT U.S.C.G. ACADEMY, NEW LONDON, CT

1. Furnace Floor Toward Rear Wall - 6/3/81

2. Furnace Floor Toward Front Wall - 6/3/81

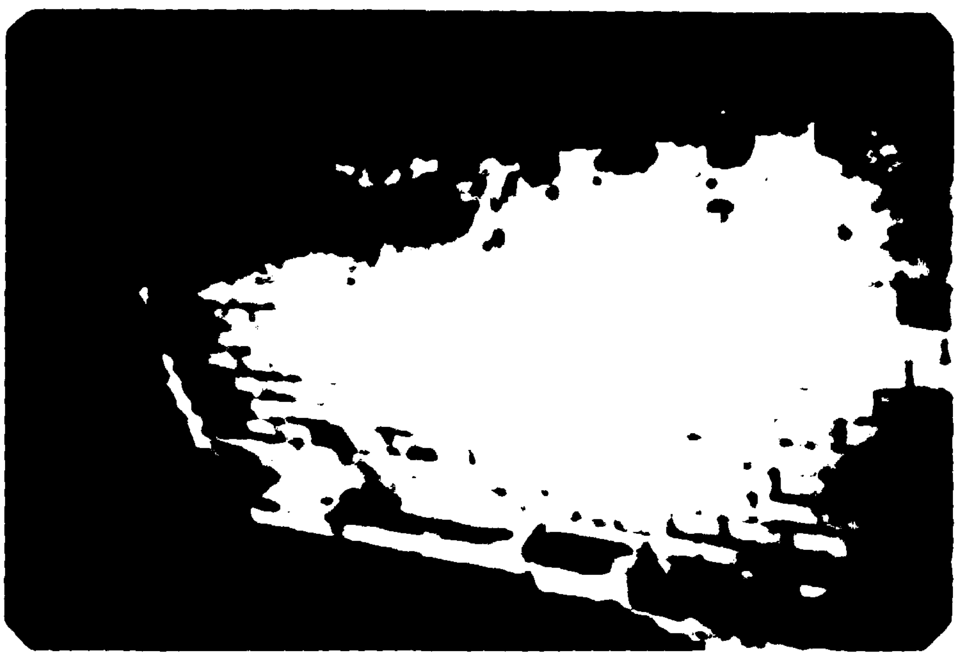


3. Left Furnace Knee Wall Toward Front Wall - 6/3/81

4. Left Furnace Knee Wall Toward Rear Wall - 6/3/81

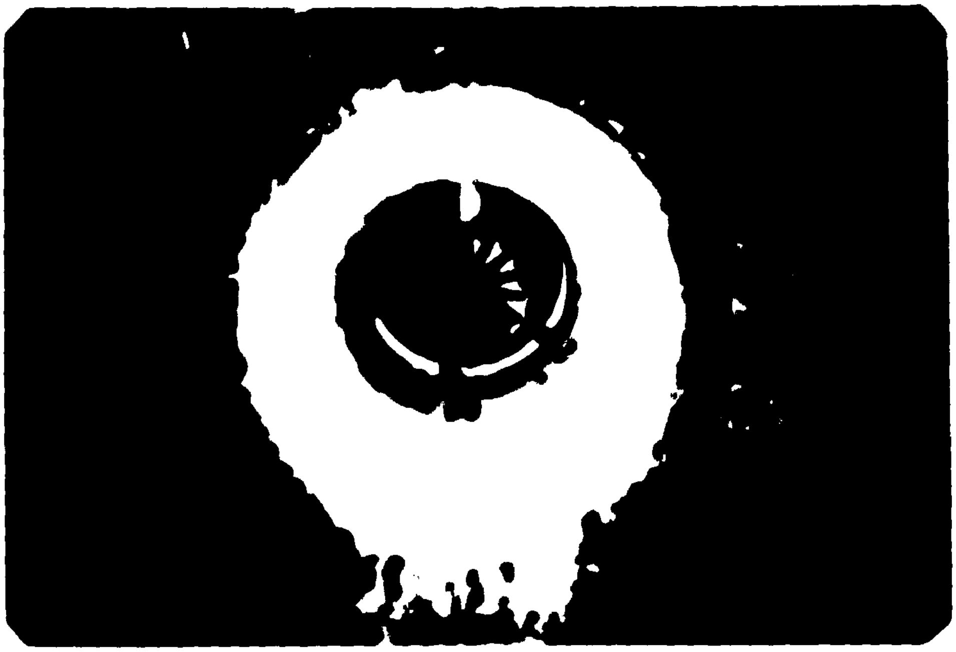
5. Left Furnace Knee Wall - Top View - 6/3/81

6. Right Furnace Knee Wall Toward Front Wall - 6/3/81



7. Right Furnace Knee Wall Toward Rear Wall - 6/3/81

8. Right Furnace Knee Wall - Top View - 6/3/81

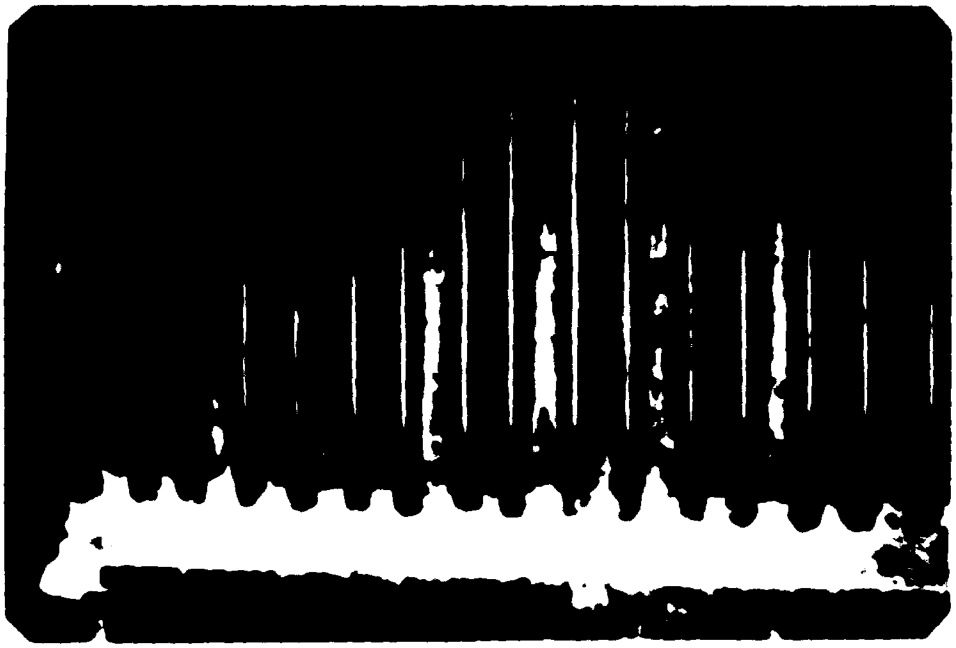


9. Right Burner Throat with Diffuser - 6/3/81

10. Left Burner Throat with Diffuser and Burner Gun - 6/3/81

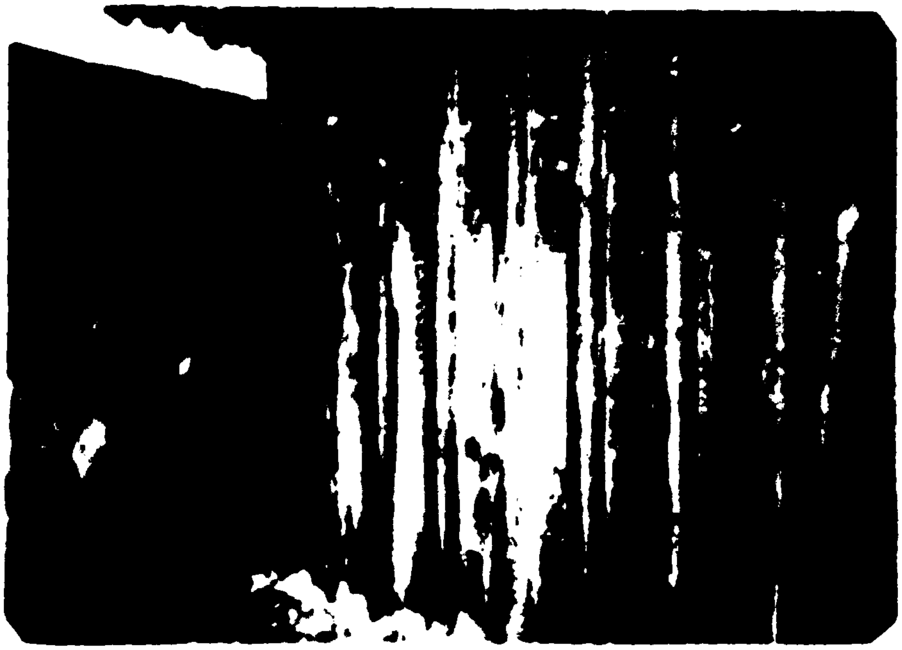
11. Right Rear Water Wall Tubes - 6/3/81

12. Left Rear Water Wall Tubes - 6/[illegible]/81

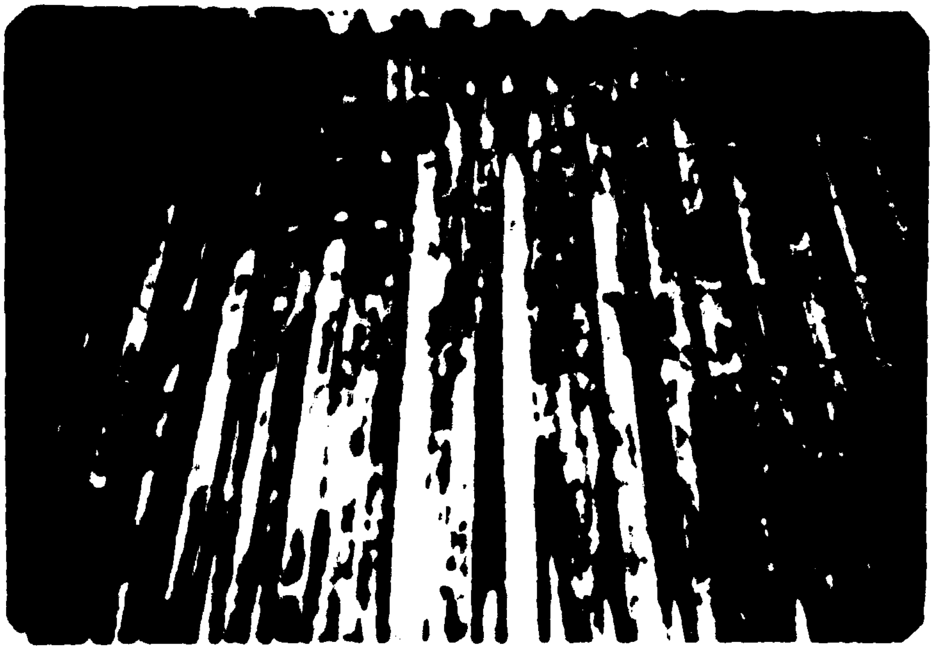


13. Rear Water Wall Tubes - 6/3/81

14. Right Water Wall Tubes Toward Boiler Front - 6/3/81



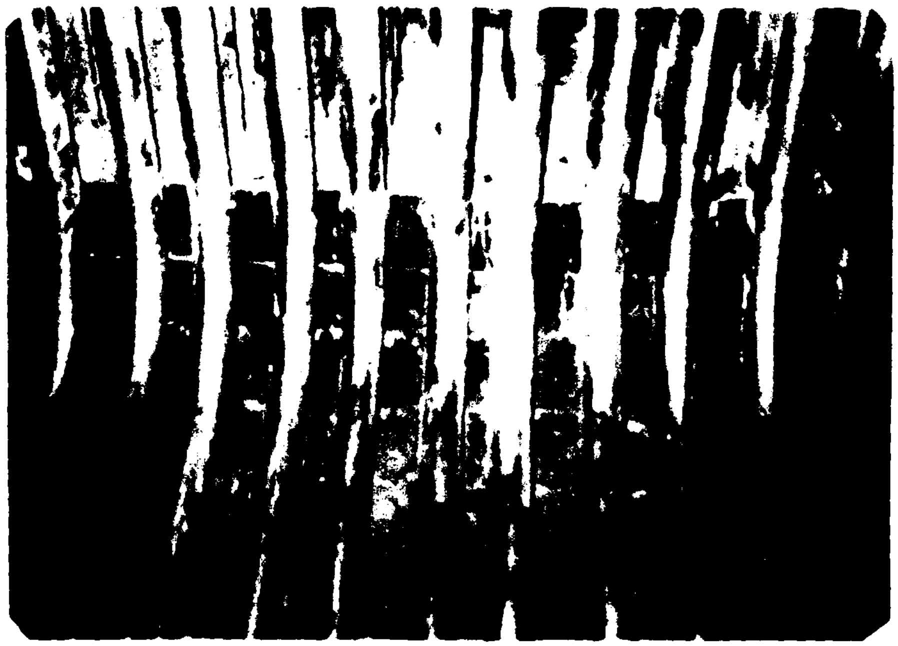
15. Left Water Wall Tubes Toward Boiler Front - 6/3/81



16. Front Water Wall Tubes - 6/3/81

17. Generating Tubes - Overhead in Furnace - 6/3/81

18. Generating Tubes with Test Windows - 6/3/81



19. First Gas Path Baffle - 6/3/81

Seaworthy Engine Systems

BOILER INSPECTION REPORT
SES PROJECT 066-01

Date of Inspection: April 1, 1982

Boiler No. 3

Location: USCG Academy, New London, CT

Inspector: R. Cass/P. Vollemans

Inspection Results:

Gas Side

Furnace Floor: Loose sintered refractory covering rear half of floor with several cracks showing. Refractory transition in front of center step separated 1½" toward front wall. Entire floor glazed with heavy accumulations against rear wall. No signs of flame impingement. See photos #1, #2 and #3 of furnace floor.

Wall Refractory: Left & right knee walls structural condition good with surfaces completely glazed. Clinker 1'x6"x4" thick (see photo #4) on left knee wall & clinker 1½'x10"x2" thick (see photo #5) on right knee wall. Rear knee wall structural condition good with heavy slagging. Front wall structural condition fair with separations between & above burners. See photo #6. Lower front wall 80% glazed.

Burner Refractory: Burner throat tile true and in fair to good condition. See photos #7 and #8 of #1 and #2 burners.

Water Wall Tubes: Greyish-black easily removable surface deposits. See photos #9 and #10 of side walls. Photo #11 is of front water wall. Rear wall tubes had 25% covering of hard scale (see photo #12) which was removable by wire brushing.

Generating Tubes: Greyish-black easily removable surface deposits of approximately 1/16" to 1/8" thickness. See photo #13 of furnace generating tubes. Generating tubes in back pass had greyish-white easily removable surface deposits (see photo #14).

Boiler Casing: Casing, bolting and gasketing in fair to good condition with evidence of frequent attention to air leaks by Academy personnel.

Flue Gas Baffles: Flue gas baffles in good condition.

Flue Gas Damper: Soft grey easily removable deposit approximately 1/16" thick on tubes beneath dampers. Condition of dampers good. See photo #15.

Gas Side General Comments: Heavy slagging on furnace floor with moderate slagging on walls. Clinkers on knee walls indicate flame impingement and incomplete combustion.

Water Side

Steam Drum: Condition good. Whitish-grey thin deposit on drum and tube surfaces. See photo #16.

Water Drum: Approximately one-half bucket of loose rusted metal. Condition good with minimal sludge deposits. Whitish-grey-brown coating in drum and on tubes. See photo #17.

Water Wall Header: Condition good with only minor rust deposits. Whitish-grey-brown coating in drum and on tubes.

Water Side General Comments: Condition good, no chemical cleaning required. Thin film removable by hose washing. See attached copy of Betz Entec System Review - April '82.

Fuel Oil System

Fuel Oil Pump: Condition operational.

Fuel Oil Heater: Condition operational. Temperature regulators in need of overhaul and/or adjustment.

Burners and Sprayer Plates: Burners are in fair to good condition with oil tubes lightly coked. Tips were new at beginning of long term test and are in fair to poor condition with numerous scratches due to mishandling.

Burner Registers: Condition good. Registers are not same as at beginning of emulsified oil test. Originals were replaced on 12/16/81 with registers from Boiler No. 2 because of repeated jamming problems.

Fuel Oil Meter: Brooks ER Positive Displacement Oscillating Piston Meter. Model ER 116HP with accuracy ± 0.5% of flow rate over range of 0.75 - 7 gpm.

Fuel Oil Treatment System: Batch treatment. Nutmeg NCC sludge solvent. Dosage ratio approximately 4000 to 1.

Fuel Oil System General Comments: Condition operational. Emulsion quality good as per photomicrograph of sample collected 3/29/82. See photo #18.

Combustion Air

Forced Draft Blower: New motor installed approximately two weeks before post long term emulsified oil tests. Condition operational.

Air Damper: Condition operational - in need of cleaning and lubrication. Linkages free.

Combustion Control System

Fuel Oil/Combustion Air Ratio Controller: Condition operational.

Feed Water System

Feed Water Pump: Condition operational.

Feed Water Regulator: Condition operational.

Feed Water Treatment System: Betz 716, 729, 733, 741. Control for corrosion, scale, sludge formation, iron control anti-carry over and with flocculent properties.

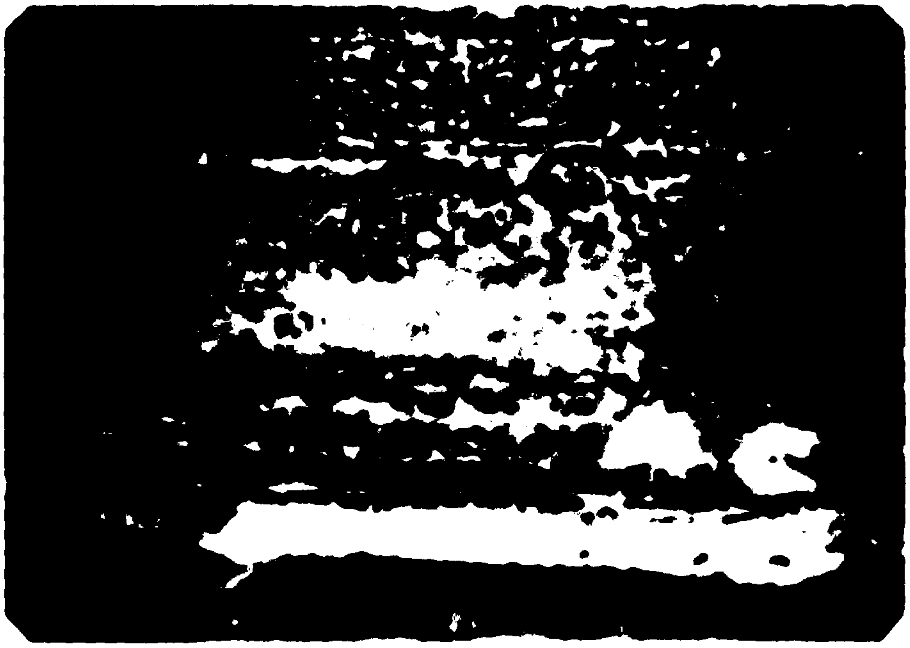
Feed Water Blowdown System: System operational.

Feed Water Meter Hoffer Model HO 1½ - 8130 SF, turbine meter with accuracy of ± 0.15% of actual reading.

Soot Blowing System

Soot Blowing Elements: Condition operational.

PHOTOGRAPHS OF BOILER NO. 3 AT
U.S.C.G. ACADEMY, NEW LONDON, CT



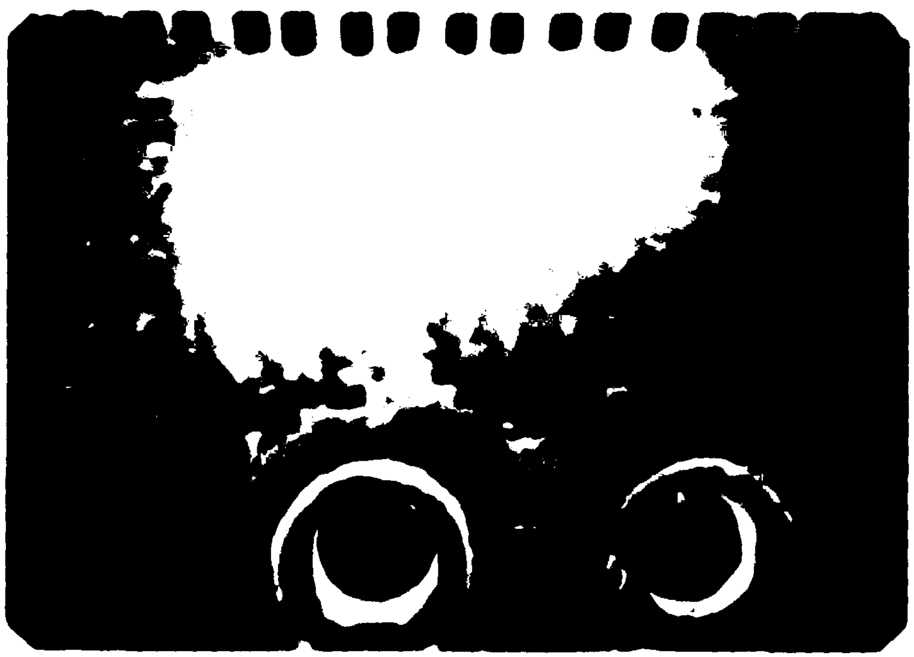
1. Furnace Floor Towards Rear Wall - 4/1/82

2. Furnace Floor Towards Front Wall - 4/1/82

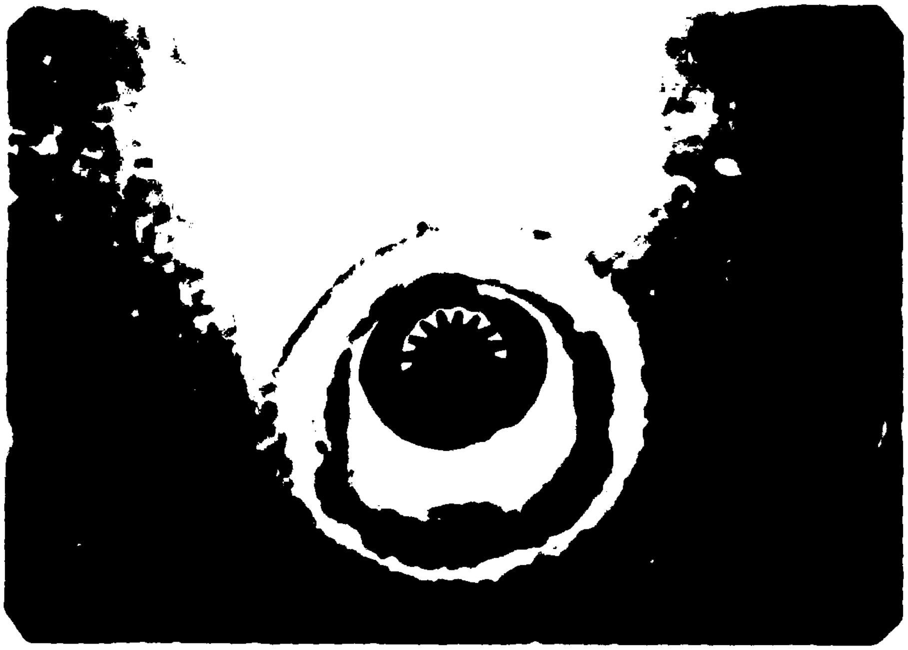
3. Furnace Floor Separation - 4/1/82

4. Left Knee Wall - 4/1/82

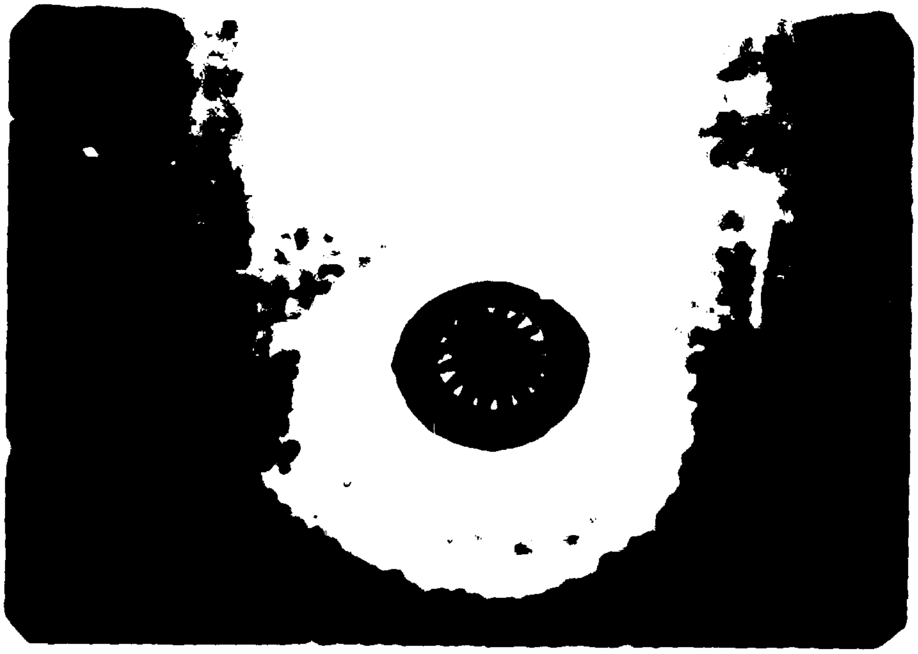
5. Right Knee Wall - 4/1/82



6. Front Wall - 4/1/82



7. Right Burner Throat with Diffuser - 6/1/82



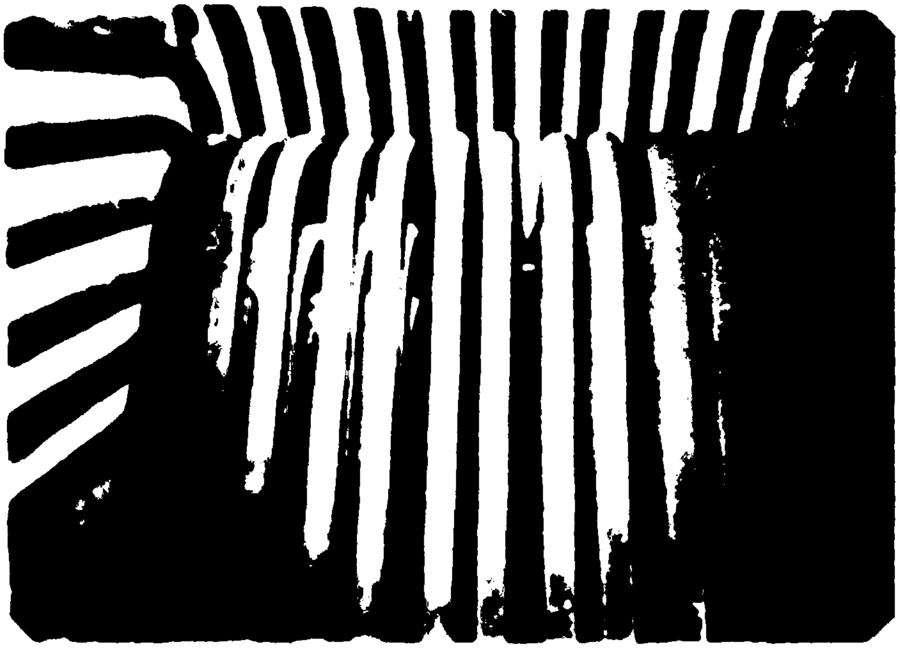
8. Left Burner Throat with Diffuser - 6/1/82

9. Right Water Wall Tubes - 4/1/82

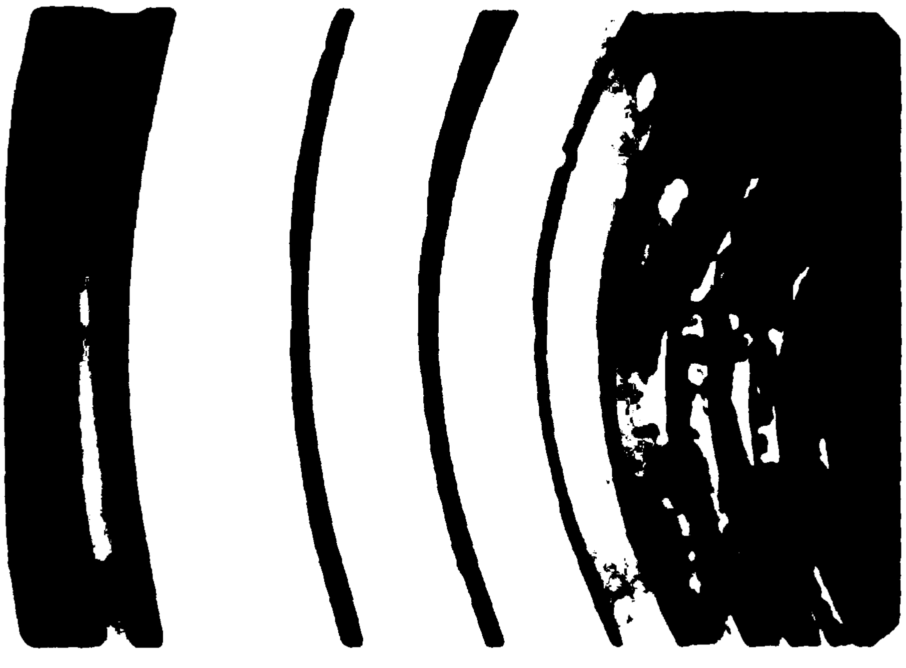
10. Left Water Wall Tubes - 4/1/82

11. Front Water Wall Tubes - 4/1/82

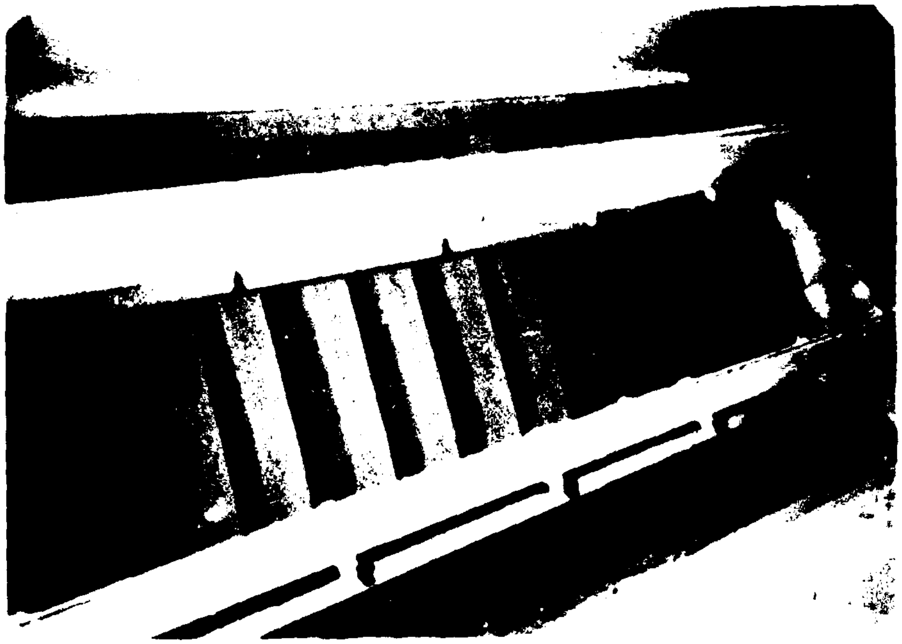
12. Rear Water Wall Tubes - 4/1/82



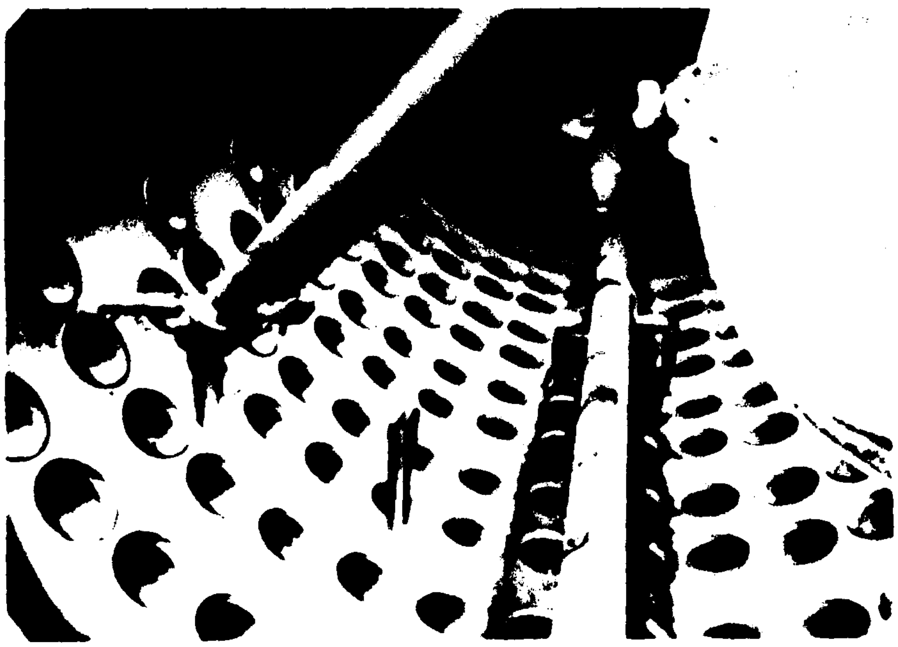
13. Overhead Furnace Generating Tubes - 4/1/82



14. Back Pass Generating Tubes - 4/1/82

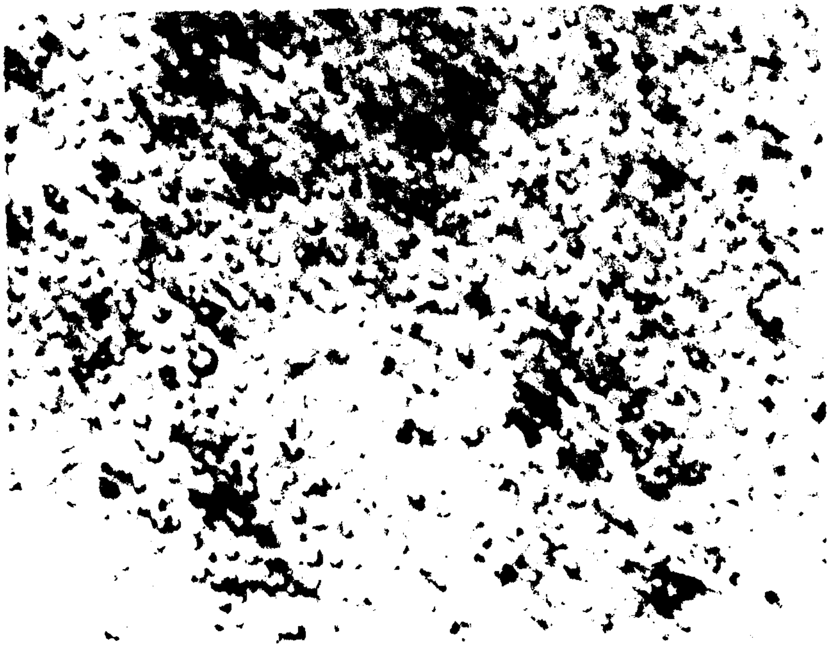


15. Flue Gas Damper and Generating Tubes - 4/1/82



16. Steam Drum - 4/1/82

17. Water Drum - 4/1/82



18. 500x Photomicrograph of 3/29/82 Fuel Sample

BETZ ENTEC INC.

HORSHAM, PENNSYLVANIA 19044

SYSTEM REVIEW

COMPANY U.S. Coast Guard Academy REPORTED TO: D. Isherwood

ADDRESS

COPY TO:

New London Ct

SYSTEM Boiler DATE: 1 Apr 82

I made an internal inspection of #3 boiler today.

There was no evidence of active corrosion nor new scale deposits. A very thin film of normal phosphate sludge was present which will wash away.

The excellent conditions found reflect the close control maintained by plant operators over the past year.

No changes in treatment or control are recommended at this time.

INVENTORY Product	Drums	Product	Drums
241	2		
214	1		
221	1		

Signed [illegible signature]

Title

ENT-207 (FOUR PART) 8060

*U.S. GOVERNMENT PRINTING OFFICE: 1982-0-361-428/2248